ANNUAL REPORT OF RESEARCH AND TECHNOLOGIC WORK ON COAL AND RELATED INVESTIGATIONS FISCAL YEAR 1952

BY R. L. BROWN AND W. H. ODE

* * * * * * * * * * **Information Circular 7663**

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
J. J. Forbes, Director

Work on manuscript completed February 1953. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7663."

August 1953

Generated on 2024-09-20 11:09 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

ANNUAL REPORT OF RESEARCH AND TECHNOLOGIC WORK ON COAL AND RELATED INVESTIGATIONS, FISCAL YEAR 1952

by

R. L. Brown[1/] and W. H. Ode[2/]

CONTENTS

	Page
Introduction and summary	1
Acknowledgments	4
Origin, composition, and properties of coal	6
Inspection, sampling, and analysis	6
Analyses of miscellaneous materials	7
Constitution, properties, and analytical methods	7
International classification and analysis of coal	7
Surface area and pore structure of coal	8
Dispersive and coking properties of coal	8
Petrographic studies of coal	8
Sulfur in lignite	10
True specific gravities of lignite and lignite char	11
Coal mining	11
Study of known recoverable reserves of coking coal	11
Floyd County, Ky.	11
Armstrong County, Pa.	11
Fayette County, Pa.	12
Jefferson County, Pa.	12
Westmoreland County, Pa.	13
Raleigh County, W. Va.	13
Coal investigations	14
Colorado	14
Maryland	14
New Mexico	15
Alaska	15
Brazil	16
Greece	16
Mining methods and practices	16
Anthracite mechanical mining research	16
Bituminous-coal-mining studies	17
Roof-bolting practices	19
Causes of fatalities in coal mines	19
Circuit-breaker protection in coal mines	20
Mine atmospheres	20
Anthracite flood prevention	22

1/ Coal Technology Coordinator, Fuels and Explosives Division, Bureau of Mines, Washington, D. C.

2/ Chemist, Bureau of Mines, Pittsburgh, Pa.

Information Circular 7663

Generated on 2024-09-20 11:08 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

Digitized by Google

Original from THE OHIO STATE UNIVERSITY

CONTENTS (Cont.)

	Page
Preparation of coal	22
Coal washing	22
Prediction of washery performance	22
Densimeter for heavy-medium plants	23
Froth flotation in western Europe and Great Britain	23
Preparation characteristics of coking coals	24
Clearfield County, Pa.	24
Fayette County, Pa.	24
Somerset County, Pa.	25
Westmoreland County, Pa.	25
Briquetting coal and char	26
Alaskan coals and chars	26
Mexican coals	26
Drying low-rank coals	27
Drying lignite and subbituminous coal	27
Moisture removal and sorption studies of lignite	27
Transportation and storage of coal	28
Hydraulic transportation	28
Storage of lignite	28
Utilization of coal and other fuels for combustion	29
Fuel engineering service	29
Utilization of fly ash	30
Disposal of radioactive wastes by incineration	31
Tests of army stoves and cookers	31
Other investigations related to fuel utilization	32
Boiler-feed-water conditioning	32
Boiler water research	33
Air and stream pollution	34
Mine-refuse fires	34
Smoke abatement	34
Stream pollution	34
Carbonization of coal	35
Survey of carbonizing properties of American coals	35
Kentucky coals	35
Pennsylvania coals	38
Virginia coals	38
West Virginia coals	39
Alaska, British Columbia, Utah, and Washington coals	39
Expansion properties of coals during carbonization	40
Spontaneous-heating tendencies of bituminous coal	42
Carbonization of fine coal in the entrained and fluidized state	43
Production of special carbons by the carbonization of noncoking coals	43
Gasification of coal and lignite	44
Gasification of lignite	44
Underground gasification	44
Research on the production of synthesis gas	47
Gasification of pulverized coal	47
Laboratory-scale experimentation	47
Pilot-plant-scale gasification at atmospheric pressure and high pressure	47
Gasification by the vortex principle	49
Feeding of pulverized coal	49
Synthesis-gas purification and analysis	49

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

CONTENTS (Cont.)

	Page
Synthetic liquid fuels by gas synthesis: Research and development	51
Properties of iron catalysts	51
Synthesis with iron catalysts	51
The oxo reaction	53
Synthetic liquid fuels by coal hydrogenation: Research and development	54
Kinetics of coal hydrogenation	54
Conversion of asphaltene	54
Conversion of anthraxylon	54
Pilot-plant operations	55
Hydrogenation of coal	55
Hydrogenation of shale-oil coker distillate	56
Separation, synthesis, and characterization of products of coal hydrogenation	56
Phenols	56
Organic bases	57
Polycyclic compounds	57
Synthetic liquid fuels demonstration plant	58
Coal-hydrogenation plant	58
Liquid-phase hydrogenation unit	58
Vapor-phase hydrogenation unit	60
Heaters and exchangers	61
New high-pressure injection pump	62
Gas-synthesis plant	63
Oxygen plant	63
Kerpely producer	63
Purification plant	63
Synthesis and distillation units	64
Synthesis run 1	64
Synthesis run 2	65
Synthesis run 3	65
Catalyst fusion and reduction units	66
Coal gasification	66
Engineering studies and cost estimates	67
Synthetic liquid fuels publications	67

5471

Generated on 2024-09-20 11:06 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

ILLUSTRATIONS

Fig.		Follows page
1.	Relation of agglutinating value to free-swelling index..	8
2.	Frequency of occurrence of various reflectance values in coal.....	8
3.	Column diagram of coal cores from test holes 29-CB, Castleman Basin, Md., with data from chemical and petrographic analysis.....	10
4.	German coal planer at Helen, W. Va.	18
5.	Plan of experimental panel for planer.....	18
6.	Distribution curve for Baum-type jig.....	22
7.	Densimeter for continuously indicating density of heavy medium.....	22
8.	Schematic engineering design of 50-ton per hour fluidized drying unit for lignite.....	26
9.	Apparatus for thermal treatment of North Dakota lignite at controlled temperatures.....	26
10.	Model incinerator used to study method for disposal of radioactive wastes.....	30
11.	Portable tent heaters being tested for the Office of the Quartermaster General.....	30
12.	Herman-Nelson heater under test.....	30
13.	Aspects to be considered in gob-pile investigation.....	34
14.	Vertical section of electrolinking underground gasification experiment.....	44
15.	Installation of electrode in coal bed.....	44
16.	Burning the gases produced in electrolinking gasification experiment.....	46
17.	Effect of oxygen-coal ratio on cost of oxygen and coal per 1,000 std. c.f. of carbon monoxide and hydrogen produced in adiabatic vortex reactor.....	48
18.	Electron micrographs of various replicas of reduced fused iron catalyst.....	50
19.	Effect of pretreatments of precipitated catalyst P 3003.24 on the composition of products obtained from it.....	52
20.	Equipment layout of experimental coal-hydrogenation plant.....	54
21.	High-pressure injection pump.....	58
22.	Vapor-phase hot stall showing new exchanger and welded supported piping.....	60
23.	Fischer-Tropsch synthesis reactor.....	62
24.	Coolant oil-circulating pumps in synthesis unit of gas-synthesis plant.....	64

Generated on 2024-09-20 11:12 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

INTRODUCTION AND SUMMARY

This report, the seventeenth in an annual series, summarizes Bureau of Mines research and technologic work on coal and related investigations for July 1, 1951, to July 1, 1952. It is based largely on publications issued during the fiscal year, although in some instances data are presented that have not been published previously. Footnote references are given to the publications so that further details on the work may be obtained.

Bureau of Mines research on the mining, preparation, and utilization of coal is directed toward developing and encouraging safer and more efficient mining practices and preparing and utilizing coals to the best advantage.

To insure that coal purchased by defense and civilian agencies of the Government met guarantees, the Bureau continued its service to these agencies by sampling and analyzing coal on a guaranteed analysis basis and by giving advice on fuel purchases. For this purpose proximate, ultimate, heating-value, and other analyses and tests were made on 11,945 samples of coal and coke from Government purchases and inspections of tipples. To assist in buying and selling coal on the world market, the Bureau continued its cooperation with a committee of the Economic Commission for Europe in developing a coal-classification system for international use and with the International Organization for Standardization in international standardization of methods of sampling and analysis of coal. Data were obtained to further clarify the fundamental nature of the structure of coal.

To provide information on potential new sources of metallurgical coke to replace depleted reserves of the Nation's best coking coals, the investigation of known recoverable reserves of coking coal in the Appalachian region was continued. Recoverable reserves of coking coal in beds 28 inches or more thick were reported for 4 counties in central and western Pennsylvania, 1 in southern West Virginia, and 1 in eastern Kentucky. In conjunction with this work, studies of the preparation and carbonization characteristics of coals from the same areas were continued. To develop additional sources of coking coals for western steel plants, an investigation of an area in western Colorado proved a reserve of over 100 million tons of coal suitable for metallurgical use.

In studies of safer and more efficient mining methods, full mechanization with a German lightweight shearing machine in combination with mechanical loading in pitching anthracite beds was found to be two and one-half times as fast as conventional hand-mining methods with costs only one-third as much. The first experiment in the United States with a German coal planer on a longwall face of a relatively thin coal bed gave about a 20 percent greater productivity, as compared with conventional mining. From a safety standpoint additional advantages for both machines were found. Factual data were obtained on the spectacular developments in the use

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

of roof bolts for roof support. A gravity-tunnel system was found to be the solution to flood prevention in certain anthracite mines. The production of coal by strip mining was reviewed.3/

Fatality and injury rates after 10 years of Federal inspection of coal mines showed a downward trend; major improvements in the coal mines contributed much to the favorable decrease in injury rates.4/ Continued effort was made to point out the major causes of injuries and methods for their prevention. Approximately 14,000 samples of mine air were analyzed to determine the adequacy of ventilation in coal mines. To insure that adequate rock dust was used in coal mines to prevent propagation of disastrous coal-dust explosions, over 6,000 samples of coal-mine dust were analyzed.

A review of coal-preparation practices in America was published;5/ a simple method of predicting coal-washery performance was developed; and a study of European practice in recovering, cleaning, and dewatering fine sizes of coal showed that froth flotation may be one solution to the troublesome problem of coal fines. In investigating the preparation characteristics of coals available for production of metallurgical coke, reports were published for four counties that produce coal available to the steel industry in western Pennsylvania. Progress was made in developing processes for briquetting Alaskan and Mexican coals and chars. Large drying plants with a capacity up to 50 tons per hour were designed for drying low-rank coals in the entrained and fluidized state.

A survey showed that coal can be transported economically by pipeline. The Bureau continued its consulting and field testing services to aid Federal agencies in the selection, testing, and use of fuel and fuel-burning equipment and in boiler-feed-water conditioning and testing. Analyses and resulting recommendations were made on over 11,000 samples of boiler water, an increase of about 16 percent over the previous year. Based on savings reported by representative plants, Government agencies saved well over $20,000,000 per year through the Bureau of Mines boiler-water-conditioning program.

The significance of American Society for Testing Materials laboratory tests for coal and coke used for combustion was critically evaluated. Design and development of an incinerator for disposal of radioactive wastes were investigated for the Atomic Energy Commission. The performance of Army stoves and cookers was evaluated for the Office of the Quartermaster General. To provide statistical background for further studies of fuel requirements and supplies, data were assembled on the use of fuels and electrical energy in 1929, 1939, and 1947.6/

The Bureau initiated an investigation into the causes and prevention of gob-pile fires and continued its work on acid mine drainage. Problems in other phases of air and stream pollution were reviewed.7/8/

3/ Yancey, H. F., The Present Status of Strip Mining in the United States: Proc. 4th Conf. Coal Research, Inc., Centralia, Wash., Dec. 7 and 8, 1951, pp. 3-4.

4/ Forbes, J. J., Ankeny, M. J., and Weaver, H. F., Federal Coal-Mine Inspection - A Decade of Progress: Bureau of Mines Inf. Circ. 7625, 1951, 47 pp.

5/ Fraser, Thomas, and Yancey, H. F., Preparation of Coal in America: Proc. United Nations Sci. Conf. Conservation and Utilization of Resources, vol. III, Fuel and Energy Resources, United Nations Dept. of Economic Affairs, New York, 1951, pp. 122-130.

6/ Lyon, W. H., and Colby, D. S., Production, Consumption, and Use of Fuels and Electric Energy in the United States in 1929, 1939, and 1947: Bureau of Mines Rept. of Investigations 4805, 1951, 90 pp.

7/ Boyd, James, Waste Problems in the Mineral Industries: Chem. Eng. News, vol. 29, 1951, pp. 4671-4673.

8/ McCabe, L. C , Interrelationship of Air Pollution and Water Pollution: Sewage and Industrial Wastes, vol. 24, No. 1, 1952, pp. 83-86.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

In the Bureau's program of coking-coal reserves, pilot-plant carbonization tests were made of 20 Appalachian coals, carbonized both singly and in blends. Certain western coals were found satisfactory for use in making metallurgical coke. Expansion tests were made to show those coals that might damage oven walls. Studies were continued to determine those coals liable to self-heat or apt to take fire spontaneously and deteriorate in coking properties during storage. Experimental work was continued on the carbonization of fine dried coal dusts in the entrained and fluidized state; a plant was designed to carbonize approximately 30 tons of dried dust per hour. Methods of overcoming shortages of metallurgical coke were described.9/

Results of tests on the gasification of anthracite bone coal were reported. The gasification characteristics of different lignites were determined in an annular metal retort pilot plant. Underground gasification experiments at Gorgas, Ala., were continued by examining a process in which an electric current passed through the coal bed carbonizes the coal and opens passageways for admitting air or oxygen without the need for underground development.

Processes developed to produce synthesis gas by atmospheric and pressure gasification were found to be feasible; coal dust was gasified with low material requirements, which promises low-cost gas if projected to commercial scale. Experimental and development work was conducted on the continuous suspension gasification of low-cost, noncaking bituminous coal with steam and oxygen in a vortex reactor.

Research on the production of synthetic liquid fuels was continued, with studies of the hydrogenation of coal, synthesis-gas production, catalyst improvement, upgrading shale-oil coker distillate, and separation, synthesis, and characterization of products of coal hydrogenation and gas synthesis.

The Synthetic Liquid Fuels Demonstration Plant at Louisiana, Mo., continued successful operations with 2 extended liquid-phase runs and 1 vapor-phase run. About 400,000 gallons of good-quality motor gasoline was produced, most of which was used in Army-fleet tests. Three integrated runs in the recently completed Gas-Synthesis Demonstration Plant were made, and valuable information was obtained concerning the operability of all parts of the plant. Engineering and cost-estimating work continued on both processes. The 30,000-barrel-per-day coal-hydrogenation plant estimate was revised and submitted to the National Petroleum Council; this revision received considerable publicity in the technical literature.

Recent technologic research on mining, preparing, and utilizing coal has given achievements of economic significance in this field that are greater than is popularly supposed.10/ However, probably no large industry in the United States is in greater need of research leading to economic improvement than the coal industry. To determine whether the Bureau's efforts on coal research are headed toward productive channels, its present work and future programs were outlined and discussed with representatives from industry and labor and from research and educational institutions at a conference in Pittsburgh, Pa., May 12-14, 1952.

9/ Fieldner, A. C., and Newman, L. L., Overcoming shortages of Metallurgical Coke: Proc. United Nations Sci. Conf. Conservation and Utilization of Resources, vol. III, Fuel and Energy Resources, United Nations Dept. of Economic Affairs, New York, 1951, pp. 164-168.

10/ Fieldner, A. C., and Brown, R. L., Economic Significance of Recent Technologic Research on Solid Fuels: Min. Eng., vol. 3, 1951, pp. 597-601.

Generated on 2024-09-20 11:06 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

ACKNOWLEDGMENTS

This report covers work done under the technical direction of the following members of the staff of the Bureau of Mines, whose cooperation and assistance in preparing data and material for use in this report and in reviewing the completed report are hereby acknowledged:

Washington, D. C.

Office of the Director

J. J. Forbes, Director
T. H. Miller, Assistant Director
W. C. Schroeder, Assistant Director
A. C. Fieldner, Chief Fuels Technologist

Fuels and Explosives Division

L. C. McCabe, chief
Harry Perry, assistant chief
T. W. Hunter, chief, Coal Branch
R. L. Brown, coal-technology coordinator, Coal Branch
J. D. Doherty, acting chief, Synthetic Liquid Fuels Branch
J. F. Barkley, chief, Fuels Utilization Branch
N. H. Snyder, supervising engineer, Fuel Inspection Section, Fuels Utilization Branch
L. R. Burdick, supervising engineer, Fuel Economy Service Section, Fuels Utilization Branch

Health and Safety Division

James Westfield, chief
W. J. Fene, assistant chief
S. H. Ash, chief, Safety Branch
M. J. Ankeny, chief, Coal Mine Inspection Branch
S. T. Reese, chief, Accident Analysis Branch

Region I (Alaska)

S. H. Lorain, Regional Director
L. G. Anderson, chief, Coal Branch, Anchorage, Alaska

Region II (Washington, Oregon, Idaho, Montana)

S. M. Shelton, Regional Director
H. F. Yancey, chief, Fuels Technology Division, Seattle, Wash.

Region IV (Wyoming, Utah, Colorado, Arizona, New Mexico)

J. H. East, Jr., Regional Director
H. P. Rue, chief, Fuels Technology Division
V. F. Parry, chief, Coal Branch, Denver, Colo.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Region V (North Dakota, South Dakota, Minnesota, Wisconsin, Iowa, Nebraska, Michigan)

Paul T. Allsman, Regional Director
Alex C. Burr, chief, Fuels Technology Division, Grand Forks, N. Dak.
R. C. Ellman, chief, Coal Preparation Section, Grand Forks, N. Dak.
J. J. Hoeppner, acting chief, Chemistry and Physics Section, Grand Forks, N. Dak.
W. H. Oppelt, chief, Utilization Section, Grand Forks, N. Dak.

Region VII (Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Florida)

Hewitt Wilson, Regional Director
B. W. Gandrud, chief, Fuels Technology Division, Tuscaloosa, Ala.
J. L. Elder, resident engineer, Underground Gasification Project, Gorgas, Ala.
J. B. Gayle, chemist-in-charge, Coke Section, Tuscaloosa, Ala.

Region VIII (Maine, New Hampshire, Vermont, New York, Massachusetts, Connecticut, Rhode Island, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Kentucky, West Virginia, Virginia, Maryland, Delaware, and Louisiana, Missouri)

H. P. Greenwald, Regional Director
J. W. Buch, chief, Anthracite Subregion, Schuylkill Haven, Pa.
H. H. Storch, chief, Fuels Technology Division, Bruceton, Pa.
M. A. Elliott, chief, Synthetic Fuels Research Branch, Bruceton, Pa.
L. L. Hirst, chief, Demonstration Plant Branch, Louisiana, Mo.
L. D. Schmidt, chief, Synthesis Gas Branch, Morgantown, W. Va.
J. D. Clendenin, chief, Preparation and Utilization Branch, Anthracite Subregion, Schuylkill Haven, Pa.
J. D. Cooner, chief, Mining Branch, Anthracite Subregion, Schuylkill Haven, Pa.
C. A. Landsidle, chief, Engineering Design Branch, Anthracite Subregion, Schuylkill Haven, Pa.
L. B. Berger, chief, Health Branch, Pittsburgh, Pa.
A. A. Berk, chief, Industrial Water Branch, College Park, Md.
R. F. Abernethy, chief, Coal-Analysis Section, Pittsburgh, Pa.
O. T. Barrett, former chief, and T. R. Jolley, chief, Coal-Preparation Section, Pittsburgh, Pa.
R. C. Corey, chief, Combustion-Research Section, Pittsburgh, Pa.
J. D. Davis (retired), former chief, and F. W. Smith, chief, Coal-Carbonization Section, Pittsburgh, Pa.
W. A. Selvig, chief, Coal-Constitution and Miscellaneous Analysis Section, Pittsburgh, Pa.
A. L. Toenges (deceased), former chief, and J. J. Dowd, acting chief, Bituminous-Coal Mining Section, Pittsburgh, Pa.
L. Goldman, chief, Boiler-Water Service Section, College Park, Md.
B. P. Martinez, supervising engineer, Stream Pollution Research Section, College Park, Md.

Region IX (Foreign)

E. W. Pehrson, Regional Director
Alan Probert, Assistant Regional Director, Washington, D. C.

5471

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The following organizations and institutions have cooperated with the Bureau in arranging for or assisting in conducting research and technologic work on coal, and their cooperation is hereby acknowledged.

Atomic Energy Commission
Defense Solid Fuels Administration
Department of Agriculture
Mutual Security Agency
National Defense, Army, Chemical Center
National Defense, Army, Quartermaster General
National Defense, Army, Signal Corps
National Defense, Navy, Office of Naval Research
Tennessee Valley Authority
Air Products, Inc.
Aluminum Co. of America
Anthracite Institute
The American Society of Mechanical Engineers
Autoclave Engineers, Inc.
Babcock & Wilcox Co.
Bituminous Coal Research, Inc.
Consolidated Engineering Corp.
Eastern Gas & Fuel Associates
Glen Alden Coal Co.
M. A. Hanna Co., Susquehanna Collieries Division
Hazleton Brick Co.
Hudson Coal Co.
International Nickel Co., Inc.
Johnstown Coal & Coke Co.
Kemmerer Coal Co.
Kentucky Coal Agency, Inc.
Koppers Co., Inc.
Lehigh Navigation Coal Co.
Los Angeles, Calif., Air-Pollution-Control District
Louisiana, Mo., Board of Education
Mining Progress, Inc.
Philadelphia & Reading Coal & Iron Co.
Pittsburgh Coke & Chemical Co.
Pittsburgh Consolidation Coal Co.
Sinclair Coal Co.
Southern Natural Gas Co.
Standard Oil Co. of Indiana
Tennessee Dept. of Conservation
Texas Power & Light Co.
Truax-Traer Coal Co.
Union Carbide & Carbon Co., Bakelite Division
United States Pipe & Foundry Co.
University of Alabama
University of North Dakota
University of Washington
University of West Virginia
University of Wyoming
Wellman Engineering Co.
Westinghouse Electric Corp.
Youngstown Mines Corp.

ORIGIN, COMPOSITION, AND PROPERTIES OF COAL

Inspection, Sampling, and Analysis

In the fiscal year 1952 enough coal was produced to equal or exceed the demand, and Federal agencies had no difficulty in obtaining bids covering their requirements. All agencies were able to make their purchases on a guaranteed analysis basis, including penalties for delivery of substandard coals. The Navy Department, purchasing coal for the Air Force, Army, and Navy, is the largest Federal purchasing agent of coal. In general, other departments purchase their own coal supply, except that the General Services Administration purchases the supply for some other agencies whose requirements are small. Contracting for coal for the fiscal year 1953 began in March and continued through the balance of the fiscal year 1952.

Coal requirements of Federal agencies for the fiscal year were estimated at approximately 6,700,000 tons. Owing to the large number of coal bids for 1952 requirements, there was a large increase in requests from Government agencies for analyses for use in evaluating coal bids. In addition, recommendations were made for awards of contracts for some agencies.

Generated on 2024-09-20 11:07 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

At the beginning of the fiscal year the tipple-sampling activities were regionalized, and the men and the equipment for this work were transferred to various regions. A total of 1,223 tipple samples was collected at 440 mines in 16 States.

At the request of the Department of the Army, 17 cargoes of coal, totaling approximately 170,000 tons, were sampled at tidewater piers. At the request of the Department of the Air Force, a school for coal samplers was conducted at Elmendorf Air Force Base, Alaska. This school was attended by representatives of the Air Force, the Army, and the Alaska Railroad. A coal-sampling school was also held at Fort George C. Meade, Md., for Air Force fuel engineers from various commands. At the request of the Department of the Navy, sampling methods at the Charleston Naval Shipyard, Charleston, S. C., were investigated, and personnel was instructed in proper sampling procedures.

Proximate, sulfur, heating-value, ultimate, and other analyses were made of 11,945 samples of coal and coke from Government purchases and inspection of tipples. Over 70 percent of these samples came from branches of the Department of National Defense and the remainder from civilian agencies of the Government. Of these samples, ash-fusion-temperature determinations were reported on 3,000 samples, free-swelling indexes on 1,054 samples, and grindability indexes on 309 samples.

Analyses of 4,548 samples of coal, coke, char, tar, and other products derived from coal were made in connection with investigations by the Bureau and other Government agencies on mining, preparation, and utilization of coal.

To insure that adequate rock dust was being used in coal mines to prevent propagation of coal-dust explosions, coal-mine inspectors of the Bureau submitted 6,193 samples of road, roof, rib, and gob dusts, representing 1,083 mine inspections. As the analyses are used in making recommendations for safety, the samples were analyzed and reported the same day as received.

The 22,686 samples of coal, coke, char, tar, residue, coal-mine dust, and other carbonaceous materials analyzed during the year required 292,272 chemical and physical tests.

Analyses of Miscellaneous Materials

Chemical analyses and tests were made of 90 samples of miscellaneous materials submitted in connection with various investigations of coal utilization, mining, and accident prevention. These samples included inert dusts proposed for rock-dusting coal mines, coal ashes and slags, boiler deposits, and related materials.

Constitution, Properties, and Analytical Methods

International Classification and Analysis of Coal

The Bureau of Mines is cooperating with the Classification Working Party of the Coal Committee, Economic Commission for Europe, in developing a coal-classification system for international use and with Technical Committee 27 on Solid Mineral Fuels, International Organization for Standardization, in international standardization of methods of sampling and analysis of coal.

Very satisfactory progress has been made in the classification work. During the year two reports, Properties of Lignites of the United States and Comments on Boundary Line of Calorific Value for Class 600 and Class 700 Coals, were prepared for the classification committee.

Generated on 2024-09-20 11:08 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

In developing the international classification scheme several small-scale tests are proposed for measuring caking and coking properties. They include the ASTM free-swelling index test, coke type by the Gray-King assay, and expansion during heating by the Audibert-Arnu dilatometer test. In connection with this work, a study was made to determine whether any correlation existed between the results of the Bureau of Mines agglutinating value test and the ASTM free-swelling test. Figure 1 shows the data that were obtained on 53 coals varying widely in agglutinating and free-swelling properties. The correlation was found to be quite poor. For practical purposes, as a rough correlation, the free-swelling index is shown to be numerically about equal to the agglutinating value.

Surface Area and Pore Structure of Coal

Data on the heat of wetting of coal in methanol and on the adsorption of methanol and water on coal has led to the concept that coal is a porous substance having a large surface area. This theory is now in doubt as a result of determination of the surface area by adsorption of nitrogen, methanol, and water on coal.11/ The areas of four coals as calculated from nitrogen adsorption were only one-fiftieth to one two-hundredth of the areas calculated from adsorption of methanol and water. The explanation of these discrepancies appears to be that nitrogen provides a measure of the true surface areas, whereas the polar molecules penetrate the coal and are sorbed on polar groups in it.

Dispersive and Coking Properties of Coal

Information obtained during extraction and coking studies of coal gave further insight into its structure.12/ Certain polycyclic compounds, for example phenanthrene, were found to disperse up to 95 percent of bituminous (Pittsburgh-bed) coal, ash and fusain being the major constituents of the residue. Coking tests indicated that the benzene-insoluble fraction of the dispersed material was agglomerating but nonswelling, whereas the soluble fraction had swelling properties only. The extracts prepared with polycyclic compounds had low ash contents; such material may be useful for manufacturing electrode carbon.

The coking properties of this bituminous and of a subbituminous Wyoming (Rock Springs) coal were similarly and profoundly affected by relatively mild oxidation or reduction. The presence or establishment of oxygen or sulfur cross linkages appears to suppress the coking ability of the coal. Reduction of the coal destroys this bonding and restores or imparts coking ability. The inversion of noncoking to coking coal can be accomplished by mild catalytic hydrogenation, using only about 0.6 percent of hydrogen at moderate pressures of 300 to 500 p.s.i.g. and at about 400° C.

Petrographic Studies of Coal

C. A. Seyler in Great Britain has applied quantitative measurements to coal reflectance, which resulted in an interesting observation that has attracted considerable attention. Seyler stated that the constituents of coal derived from wood or bark excluding spores, cuticles, and resins, have reflectances that vary discontinuously and can be arranged in a fixed series of nine steps that are related to each other by a geometrical progression.

11/ Lecky, J. A., Hall, W. K., and Anderson, R. B., Adsorption of Water and Methanol on Coal: Nature, vol. 168, 1951, pp. 124-125.

12/ Orchin, M., Golumbic, C., Anderson, J. E., and Storch, H. H., Studies of the Extraction and Coking of Coal and Their Significance in Relation to its Structure: Bureau of Mines Bull. 505, 1951, 15 pp.

Generated on 2024-09-20 11:18 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

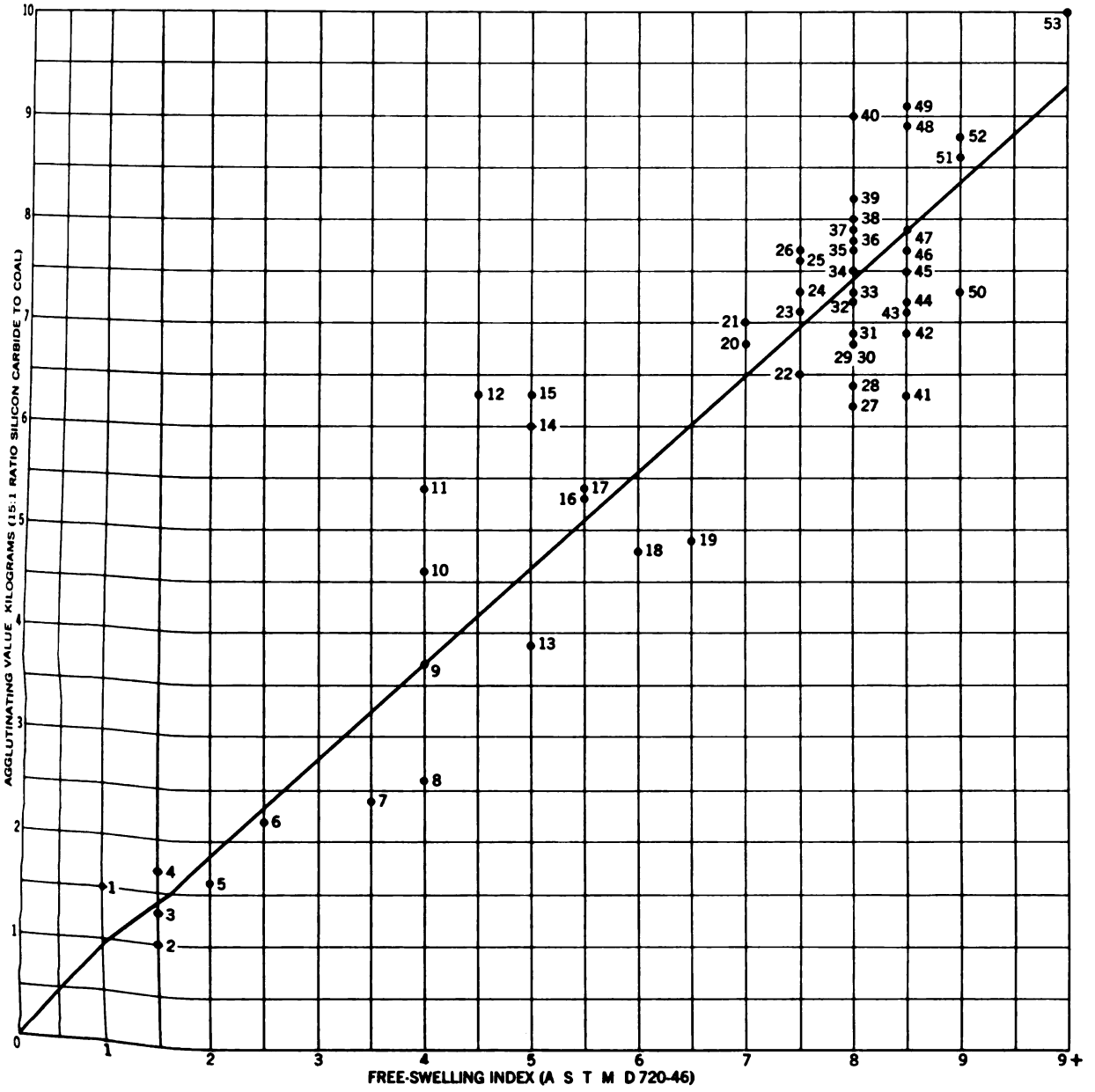

Figure 1. - Relation of agglutinating value to free-swelling index.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:09 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

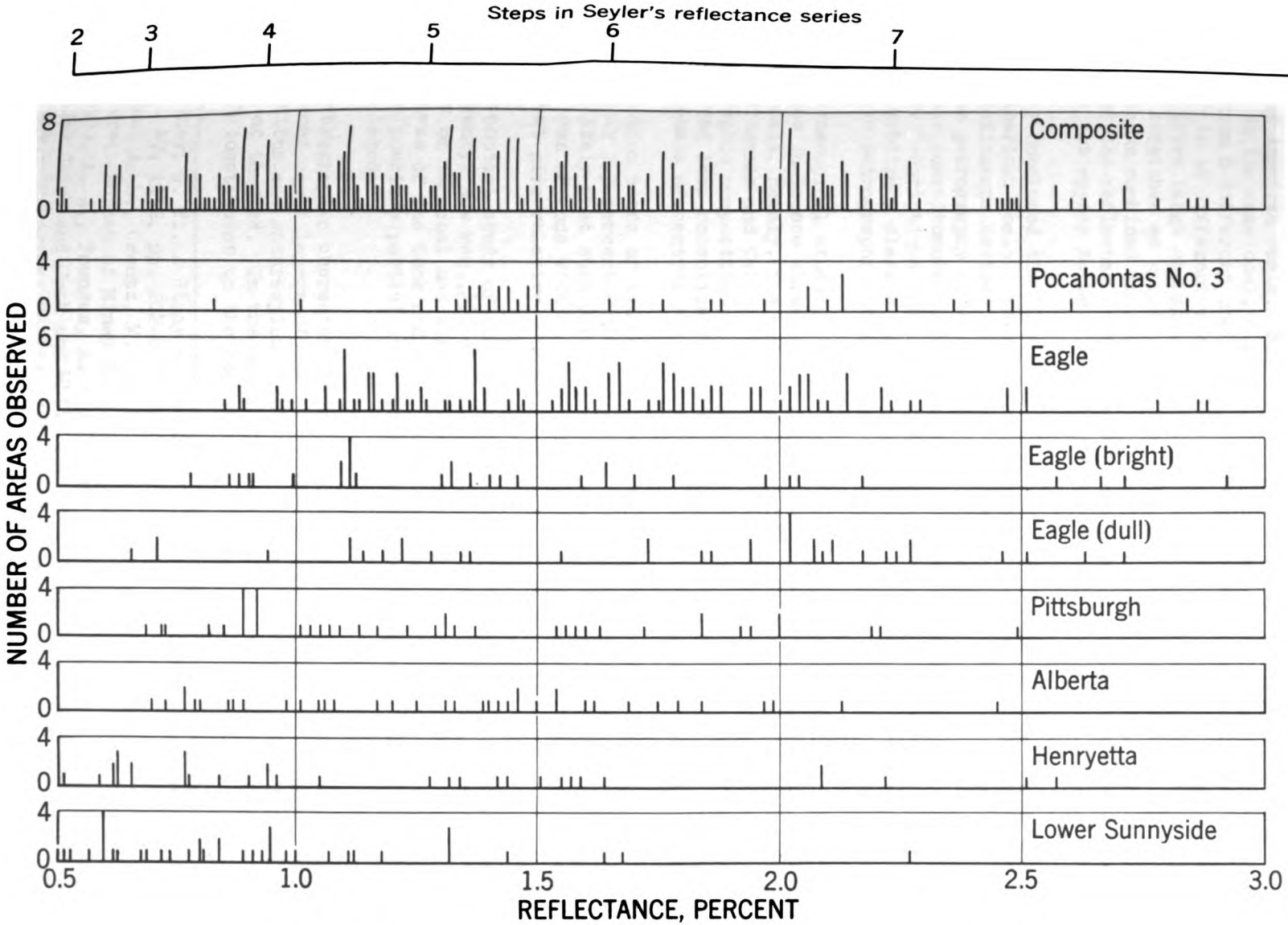

Figure 2. - Frequency of occurrence of various reflectance values in coal.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Reflectance studies by two procedures to test Seyler's findings[13] were made of a number of American coals. For example, to investigate components of different reflectance in the same coal, 8 series of determinations were made on sample blocks of attritus from 6 different coals. In 7 of these sets, 6 observations were made on each of 35 to 40 different minute areas of uniform reflectance. These were made at random on areas large enough to fill the photometer field and were as uniform and free from scratches as possible. These data are shown in figure 2. All readings also are shown combined in one composite graph. According to Seyler, a discontinuous grouping of the reflectance values should occur at or near the steps in the series. There does not appear to be any such ordered arrangement.

It was concluded that Seyler's reflectance work is not substantiated by this study on American coals. However, his descriptions of the variations in reflectance of the constituents derived from woody tissue is a significant and valuable contribution to the petrography of coal. They offer an objective basis for classifying the petrographic constituents that may become a useful complement to the subjective qualitative descriptions that have been used heretofore. It may be possible to establish arbitrary classes or limits of reflectance that can be used as a basis for quantitative petrographic analysis of either columnar or crushed coal samples.

A microscopical study of samples of lignitic coal collected by Bureau engineers from 7 mines in Greece showed that they resemble 2 important varieties of American lignitic coals, namely, the xyloid lignite of North Dakota and the attrital lignite found in Arkansas and California.[14] In spite of the similarity to American lignites in petrographic composition, the Greek lignites by visual comparison are more earthy-appearing and less consolidated. They more closely resemble in outward appearance the brown coals of central Europe than the compact and darker American lignites.

Extraction tests of two Greek lignites, using benzene as solvent, gave yields of approximately 1.5 percent extractable material. The low yield of waxy product makes it seem unlikely that such Greek lignites can be successfully briquetted without binder, as can be done with certain German and Czechoslovak brown coals and American lignites that give relatively large yields of extractable wax.

Microscopical study of column samples collected from coal deposits near Cerrillos, Santa Fe County, New Mex.,[15] showed that the systematic variation in the petrographic composition of the coal had significance in explaining the spotty character and variable thickness of the Cook and White bed. Information from the petrographic investigation made possible partial interpretation of the swamp environment in which the coal accumulated.

The petrographic character of the Cook and White bed is marked by a succession of nine almost equal layers of coal in which the predominant constituent is alternately attritus and anthraxylon. This pattern continues vertically through about two-thirds of the bed. In the upper portion of the bed attritus continues as the predominant constituent to the top of the bed.

13/ McCartney, J. T., A Study of the Seyler Theory of Coal Reflectance: Econ. Geol., vol. 47, 1952, pp. 202-210; discussions, pp. 211-215.

14/ Toenges, A. L., Crentz, W. L., Parks, B. C., and Abernethy, R. F., Lignite in Greece: Bureau of Mines Bull. 502, 1951, 57 pp.

15/ Turnbull, L. A., Toenges, A. L., Davis, J. D., Reynolds, D. A., and Parks, B. C., Miller Gulch and Cook and White Coal Beds Near Cerrillos, Santa Fe County, N. Mex.: Reserves; Coking, Petrographic, and Chemical Properties: Bureau of Mines Rept. of Investigations 4814, 1951, 29 pp.

5471

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Petrographic study showed that the coals of the Coal Creek district of Gunnison County, Colo.,16/ are remarkably uniform in physical appearance and composition and relatively low in ash-forming mineral matter. The coal is bright lustered and fine- to micro-banded. The coal is hard and when crushed produces a minimum amount of dust. The Lower coal, which is fairly typical of those in the Coal Creek area, is classified as bright coal of the humic attrital type. The fine particle size of the mineral matter and its uniform dispersion through the coal suggest that poor results can be expected in ash reduction by normal coal-cleaning methods.

Diamond-drill testing in the Castleman Basin, Garrett County, Md.,17/ gave recovery of 194 core samples totaling 358 feet of coal-bed thickness. The cores from test hole 29-CB, nearly centrally located in the Castleman Basin, representing the five most important coal beds in the field, were selected for special petrographic study, the results of which are shown in figure 3.

It was found that, by crushing the coal to minus-8-mesh size and separating at 1.55 specific gravity, the float coal consisted predominantly of two components of low ash content: Anthraxylon, with less than 3 percent ash, and bright attrital coal, with less than 8.4 percent ash, associated with lesser amounts of the two relatively high ash components, dull attrital coal, and fusain. The sink product consisted of kaolinite, calcite, and pyrite associated with particles of carbonaceous shale, bone coal, and mineralized fusain. Ash in the float coal probably could be reduced further by eliminating dull attrital coal and fusain by gravity separation at some specific gravity lower than 1.55, but this gain would be offset by an appreciable sacrifice of combustible material.

Petrographic examination was made of a column sample and of lumps of stoker-size run-of-mine lignite from the Dakota Collieries mine, Zap, Mercer County, N. Dak. In connection with this work, a technique was developed for preparing thin sections of particles of lignite of minus-1/8-inch size.

Sulfur in Lignite

The relation of volatile sulfur to fixed sulfur was determined in samples of lignite from 13 different mines. The ratio of volatile to total sulfur was significantly lower than that reported by Parr for older coals. The average volatile sulfur was 36.3 percent of the total.

Samples of different lignites were heated and brought to constant weight at from 400° to 900° C. The amount of sulfur remaining in the ash was found to be inversely proportional to the temperature. The kind of sulfur, organic or inorganic, also influenced the percentage of total sulfur retained by the ash. From 37.7 to 66.7 percent of the sulfur present in the original lignite was retained by the ash when heated to constant weight at different temperatures. In most cases analysis of the ash indicated enough CaO for the sulfur to be held in the ash as $CaSO_4$. Most of the sulfur was present as a water-soluble sulfate.

16/ Toenges, A. L., Turnbull, L. A., Davis, J. D., Reynolds, D. A., Parks, B. C., Cooper, H. M., and Abernethy, R. F., Coal Deposit, Coal Creek District, Gunnison County, Colo.: Reserves, Coking Properties, and Petrographic and Chemical Characteristics: Bureau of Mines Bull. 501, 1952, 83 pp.

17/ Toenges, A. L., Williams, Lloyd, Turnbull, L. A., Parks, B. C., O'Donnell, H. J., Abernethy, R. F., Ode, W. H., and Waage, Karl, Castleman Basin, Garrett County, Md., Coal Beds in Central Part; Reserves; Petrographic and Chemical Characteristics of Coals; Stratigraphy of Area: Bureau of Mines Bull. 507, 1952, 122 pp.

Generated on 2024-09-20 11:11 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

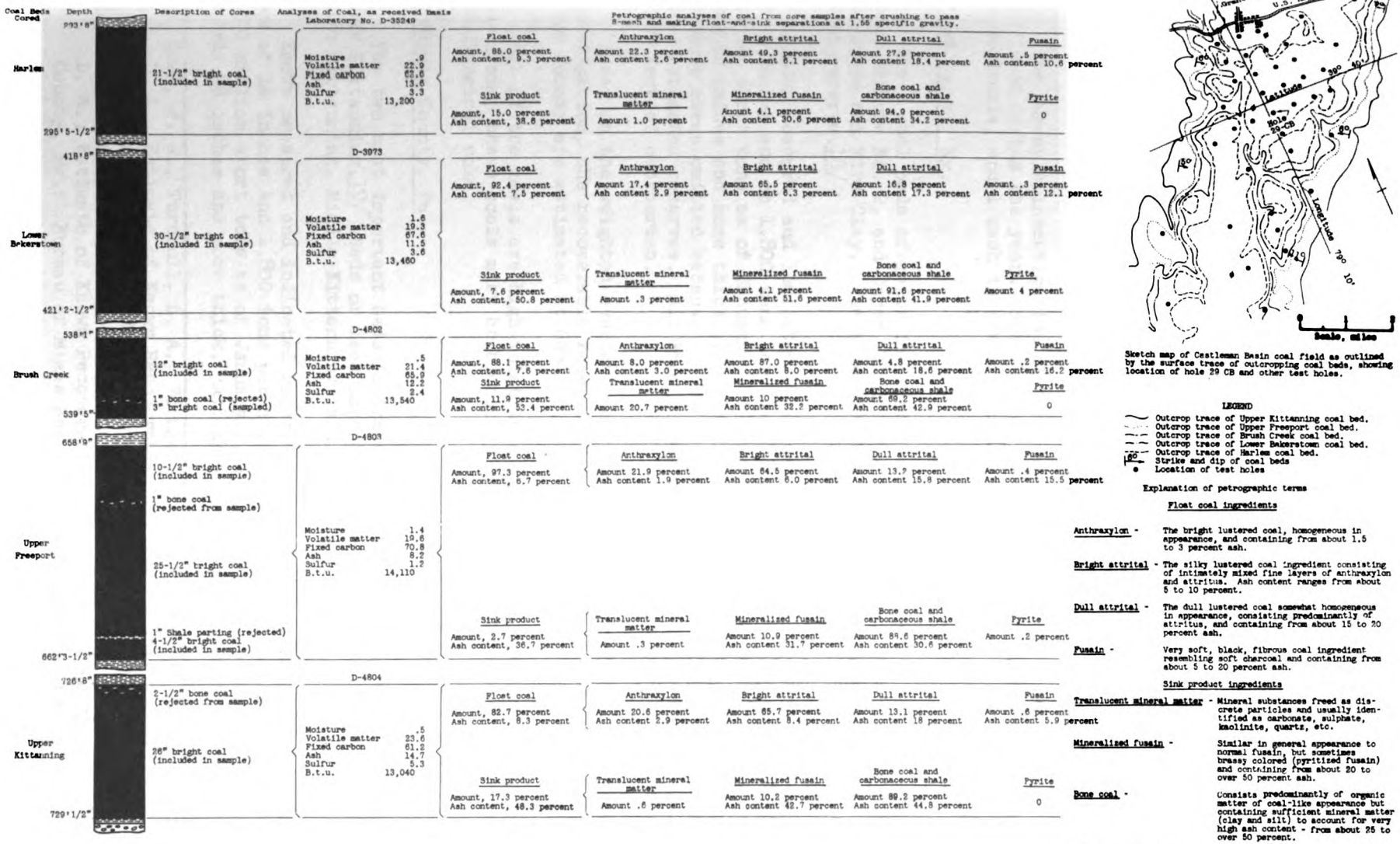

Figure 3. - Column diagram of coal cores from test hole 29-CB, Castleman Basin, Md., with data from chemical and petrographic analysis.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

True Specific Gravities of Lignite and Lignite Char

The true specific gravity of several lignites and lignite chars were determined. The values ranged from 1.261 for natural lignite with 38.5 percent moisture to 1.550 for dry lignite. A direct relationship between ash content and specific gravity was established for lignite and lignite char. The specific gravity of char samples ranged from 1.812 to 2.396.

COAL MINING

Study of Known Recoverable Reserves of Coking Coal

The Bureau's investigation of known recoverable reserves of coking coal were continued during the year. Six county reports were published, 4 for counties in Pennsylvania, and 1 each in Kentucky and West Virginia.

Floyd County, Ky.

The 3 coal beds of major importance in Floyd County are the Upper Elkhorn No. 3, Upper Elkhorn No. 2, and Upper Elkhorn No. 1; the 2 beds of minor importance are the Winifrede and Fire Clay. The Upper Elkhorn No. 3 bed contains the largest remaining known reserve.18/

Known measured and indicated reserves in all beds, based on minimum bed thickness of 14 inches and on 1,800 tons per acre-foot of coal in place, are estimated at 1,670 million short tons as of January 1, 1949. Of this total, 1,305 million tons are in beds 28 inches and more thick. Should future drilling or development prove reserves in those areas omitted because of lack of data, such reserves should be added to the total estimated reserves. All known reserves in Floyd County are under less than 2,000 feet of overburden.

Based on the weighted average recovery of 53.23 percent, as determined by this investigation, the recoverable reserves for all beds 28 inches and more thick in Floyd County are estimated at 695 million short tons as of January 1, 1949.

All of the coals are high-volatile A bituminous. Except when carbonized in beehive ovens, these coals must be blended with higher-rank coals to produce high-quality metallurgical coke.

Armstrong County, Pa.

The two most important beds in Armstrong County are the Upper Freeport and the Lower Kittanning.19/ Beds of less importance are the Pittsburgh, Lower Freeport, Upper Kittanning, Middle Kittanning, and Clarion.

Known measured and indicated reserves in all beds, based on a minimum bed thickness of 14 inches and 1,800 tons per acre-foot of coal in place, are estimated at 1,550 million short tons as of January 1, 1949. Of this total, 1,242 million tons is in beds 28 inches and more thick. All known reserves in Armstrong County are under

18/ Dowd, J. J., Turnbull, L. A., Toenges, A. L., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Floyd County, Ky.: Bureau of Mines Rept. of Investigations 4813, 1951, 16 pp.

19/ Dowd, J. J., Turnbull, L. A., Toenges, A. L., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Armstrong County, Pa.: Bureau of Mines Rept. of Investigations 4801, 1951, 16 pp.

Generated on 2024-09-20 11:14 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

less than 2,000 feet of overburden. Areas in each bed were omitted from the estimate because not enough data are available relative to the bed characteristics to make an estimate that conforms with the definition of measured and indicated coal adopted for this study. Should future drilling or development prove reserves in these areas, such reserves should be added to the total estimated reserves.

The recoverable reserves for all beds 28 inches and more thick are estimated at 574 million tons based on the weighted average recovery of 46.24 percent.

All coals of this county are high-volatile A bituminous. Few, if any, coals from Armstrong County have been used to produce metallurgical coke. If blended with higher rank coals, they probably would produce strong coke.

Fayette County, Pa.

The 2 coal beds of major importance in Fayette County are the Pittsburgh and Sewickley; the 5 beds of minor importance are the Waynesburg, Redstone, Upper Freeport, Lower Kittanning, and Brookville-Clarion. The Upper Freeport bed contains the largest remaining known reserve.20/

Known measured and indicated reserves in all beds, based on a minimum bed thickness of 14 inches and on 1,800 tons per acre-foot of coal in place, are estimated at 943 million short tons as of January 1, 1950. Of this total, 841 million tons is in beds 28 inches and more thick. All known reserves in Fayette County are under less than 2,000 feet of overburden. Areas in each bed except the Pittsburgh were omitted from the estimate because available data relative to the bed characteristics are insufficient for making an estimate that conforms with the definitions of measured and indicated coal adopted for this study. Should future drilling or development prove reserves in these areas, such reserves should be added to the total estimated reserves.

Based on the weighted average percentage recovery of 55.41 percent, as determined by this investigation for all beds in Fayette County, the recoverable reserves in beds 28 inches and more thick are estimated at 460 million short tons as of January 1, 1950.

The coals are high-volatile A and medium-volatile bituminous. Generally they are coking, but coals from all beds except the Pittsburgh usually are blended when used to make metallurgical coke.

Jefferson County, Pa.

The Lower Freeport is the most important coal bed in Jefferson County. Seven other beds occur in the county - Mahoning, Upper Freeport, Upper Kittanning, Middle Kittanning, Lower Kittanning, Clarion, and Brookville - but the annual production from the Lower Freeport bed is as much as the combined output from all other beds. The Lower Kittanning bed contains the largest remaining known reserve.21/

Known measured and indicated reserves in all beds, based on a minimum bed thickness of 14 inches and 1,800 tons per acre-foot of coal in place, are estimated at 710 million short tons, as of January 1, 1950. Of this total, 489 million tons is in beds

20/ Dowd, J. J., Turnbull, L. A., Toenges, A. L., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Fayette County, Pa.: Bureau of Mines Rept. of Investigations 4807, 1951, 19 pp.

21/ Dowd, J J., Toenges, A. L., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Jefferson County, Pa.: Bureau of Mines Rept. of Investigations 4840, 1952, 18 pp.

Generated on 2024-09-20 11:10 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

28 inches and more thick. All known reserves in Jefferson County are under less than 2,000 feet of overburden. Areas in each bed were omitted from the estimate because available data relative to the bed characteristics are insufficient for making an estimate that conforms with the definitions of measured and indicated coal adopted for this study. Should future drilling or development prove reserves in these areas, they should be added to the total estimated reserves.

Based on the weighted average recovery of 51.53 percent, as determined by this investigation, the recoverable reserves for all beds 28 inches or more thick in Jefferson County are estimated at 252 million short tons as of January 1, 1950.

The coals of this county are high-volatile A bituminous rank. Although the coals from this county generally are classed as coking, they have been used mostly for other purposes because larger tonnages of premium coking coals have been available. As all of the Jefferson County coals are high-volatile A bituminous, they should be blended with higher-ranking coals for carbonization in modern coke ovens to improve the physical properties of the coke.

Westmoreland County, Pa.

The two most important beds in Westmoreland County are the Pittsburgh and Upper Freeport; beds of minor importance are the Waynesburg, Redstone, Lower Freeport, and Lower Kittanning.22/

Known measured and indicated reserves in all beds, based on a minimum thickness of 14 inches and 1,800 tons per acre-foot of coal in place, are estimated at 922 million short tons as of January 1, 1950. Of this total, 899 million tons is in beds 28 inches and more thick. All known reserves in Westmoreland County are under less than 2,000 feet of overburden. Should future drilling or development prove reserves in areas omitted from the estimate because of insufficient data, such reserves should be added to the total estimated reserves.

The recoverable reserves for all beds 28 inches and more thick are estimated at 523 million tons based on the weighted average recovery of 58.25 percent.

The coals of this county are high-volatile A and medium-volatile bituminous rank and generally coking. However, coal from all beds except the Pittsburgh usually are blended when the coal is used to make metallurgical coke.

Raleigh County, W. Va.

The six coal beds of major importance in Raleigh County are the Pocahontas No. 4, Beckley, Pocahontas No. 3, Sewell, Winifrede, and Campbell Creek-No. 2 Gas. The six beds of minor importance are the Eagle, No. 5 Block, Powellton, Hernshaw, Fire Creek, and Pocahontas No. 6.23/ The Beckley bed contains the largest remaining known reserve.

Known measured and indicated reserves in all beds, based on a minimum thickness of 14 inches and 1,800 tons per acre-foot of coal in place, are estimated at 2,532

22/ Dowd, J. J., Turnbull, L. A., Toenges, A. L., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Westmoreland County, Pa.: Bureau of Mines Rept. of Investigations 4803, 1951, 16 pp.

23/ Dowd, J. J., Toenges, A. L., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Raleigh County, W. Va.: Bureau of Mines Rept. of Investigations 4893, 1952, 37 pp.

Generated on 2024-09-20 11:06 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

million short tons as of January 1, 1949. Of this total, 2,237 million tons is in beds 28 inches and more thick. Areas were omitted where there were insufficient data; should future drilling or development prove reserves in these areas, they should be added to the total estimated reserves.

Based on the weighted average recovery of 57.71 percent, the recoverable reserves for all beds 28 inches or more thick in Raleigh County are estimated at 1,291 million tons as of January 1, 1949.

Raleigh County coals are low-volatile, except those from No. 5 Block, Winifrede, and Powellton beds, which are high-volatile A or a medium-volatile coal, and the Sewell bed, which is either a medium- or low-volatile coal.

The Raleigh County coals rank among the most strongly coking of the country. The Pocahontas No. 3-bed coal long has been regarded as the premier low-volatile coking coal and has been used in Canada and all States east of the Mississippi River that produce metallurgical coke. Owing to the expanding properties of the low-volatile coals, blends with high-volatile coals ordinarily are used for carbonizing in coke ovens.

Coal Investigations

Colorado

An investigation by diamond drilling of the coal beds in the Coal Creek district, Gunnison County, Colo., was reported.24/ This work was undertaken to develop additional reserves of coking coal in the West to supplement proved reserves in the Sunnyside bed of Utah, and to develop, if possible, reserves of coal with coking qualities superior to Lower Sunnyside coal.

Three minable beds of high-volatile B bituminous coal containing 109 million tons of metallurgical-grade fuel occur in the area investigated.

Pilot-scale carbonization tests were made of 8-inch-diameter coal cores from diamond-drill holes in the north and south ends of the area. Similar tests were made using two samples of coal from the Lower Sunnyside bed. These tests showed that the coke made from the lower bed coal is better than that made from the Lower Sunnyside-bed coal and that coke made from the coals in the Coal Creek bed are suitable for metallurgical use based on western blast-furnace practices. A proposed projection of a mine layout and the estimated investment and mine-operating cost are included in the report.

Maryland

The results of diamond drilling, engineering examination, and geologic study of an area of 14,700 acres in the Castleman Basin, Garrett County, Md., were published.25/ Operating and abandoned mines and coal prospects were examined where accessible, and all available maps and information regarding mined-out areas were obtained. Also, the thickness and extent of the coal beds were determined from cores obtained from 40 diamond-drill holes. Eleven coal beds were penetrated in drilling. These beds, in descending stratigraphic order, are: Harlem, Upper Bakerstown, Lower Bakerstown, Brush Creek, Upper Freeport Rider, Upper Freeport, Upper Kittanning, Middle Kittanning, Lower Kittanning, Mount Savage, and Mercer.

24/ See footnote 16.
25/ See footnote 17.

Generated on 2024-09-20 11:06 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The estimated reserves of coal (measured, indicated, and inferred) 14 inches or more thick in the Harlem, Lower Bakerstown, Brush Creek, Upper Freeport, Upper Kittanning, and Middle Kittanning beds total over 232 million tons.

Four beds contain areas of coal over 28 inches thick. Of these beds, the Upper Freeport, which contains over 37 million tons of coal over 28 inches thick, is the most important.

New Mexico

The results of an investigation of the coal beds near Cerrillos, New Mex., was reported.26/ This study was undertaken as part of a general program to determine sources of metallurgical coal for western steel plants. The work was confined to the Miller Gulch and Cook and White coal beds.

Results of four diamond-drill holes and examination of underground operations, abandoned mines, and outcrop prospects did not develop a reserve of coal in either the Cook and White or Miller Gulch beds. Further investigation of the area is not recommended.

Alaska

The objectives of the Bureau's coal investigations in Alaska are to create, through the development of new mines, supplies of coal adequate for the fuel requirements of military installations and essential civilian needs and to develop a process or processes for treating the subbituminous coals in the Fairbanks area to provide a storable, shippable fuel that will not ignite spontaneously.

An investigation of bituminous-coal deposits near Eska, Matanuska coal field, showed that the estimated recoverable reserves in the vicinity of the Eska No. 2 mine are 699,300 tons, which is not enough to justify development of a modern mine in this area.27/ East of Eska Creek the recoverable reserves are deposited in small areas separated by faults. Although these reserves are estimated to be 974,500 tons, development in this area will not be favorable for low-cost mining.

Investigation by diamond drilling in the Wishbone Hill area of the Matanuska field was continued in an attempt to develop a mine site and to extend the known coal reserves in this field. One deep combination churn- and diamond-drill hole was completed. Two new holes were begun, one vertical hole at about the axis of the Wishbone Hill syncline and a horizontal hole to intersect the coal beds in the south limb of the syncline. Plans were made to open the Buffalo and Premier mines at the west end of the Wishbone Hill syncline, and rehabilitation of these two mines is under way. Increased production in the Matanuska field is essential to supply coal to the fuel-deficient Anchorage area.

Drilling adjacent to a coal strip mine at Houston on the Alaska Railroad was undertaken, and one core-drill hole was completed. Plans were made to drill two additional holes in this area. This drilling will determine whether the coal beds being stripped are present under heavier overburden adjacent to this operation.

26/ See footnote 15.

27/ Jolley, T. R., Toenges, A. L., and Turnbull, L. A., Bituminous-Coal Deposits in the Vicinity of Eska, Matanuska Valley Coal Field, Alaska: Bureau of Mines Rept. of Investigations 4838, 1952, 87 pp.

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Brazil

A survey was made to appraise the physical conditions and technologic development of the coal industry of Brazil so that plans for expansion of production in that country might be prepared on a sound basis.28/

Coal production in the three southernmost States of Rio Grande do Sul, Santa Catarina, and Parana totals about 2 million tons annually. The beds are horizontal, with moderately good physical conditions for mechanized mining by American methods. Experimental operations are now being made with chain-cutting machines and mechanical drilling equipment.

In the State of Santa Catarina, where coking coal is produced for the American-financed National Steel Co., production will have to be doubled to meet the requirements of the expanded steel-production schedule after completion of the current plant-building program at the end of 1953. Plans for the coal-mining expansion are based on the findings of the Bureau's study.

Greece

The results of an investigation of mining conditions in Greek lignite mines were published.29/ The Economic Cooperation Administration, which requested the investigation, asked for recommendations for the introduction of methods and practices to increase production and decrease the cost of mining and to suggest plans for the development of mines to supply fuel for a power plant.

Studies were made of mining operations in the Athens Basin, Rafina and Oropos districts, Kimi and Aliveri areas, on the island of Euboea, and the Peloponnese in the vicinity of Kalamai. Aliveri and Kimi are the only areas in which the inferred reserves of lignite justify development of mechanized mines to produce an annual output of more than 500,000 tons over a considerable period of time. Production can be increased and costs reduced at all lignite mines without large outlay of capital by improving mining methods and practices.

Mining Methods and Practices

Anthracite Mechanical Mining Research

The effect of using lightweight, low-powered shearing machines in combination with mechanical loading on the rate of advance for driving coal gangways in anthracite mines was investigated, and the results were compared with those of existing hand-mining methods under similar conditions.30/ Tests with the machines were made in an underground experimental section in which 78 feet of gangway, 108 feet of return airway, and 80 feet of ventilation chute were driven. It was shown that full mechanization is two and one-half times as fast as conventional hand methods on a linear-feet-advance-per-shift basis, and it costs slightly more than one-third as much. Additional advantages, from a safety standpoint, were found in the use of

28/ Good, J. E , Abreu, Alvaro, and Fraser, Thomas, The Coal Industry of Brazil, Part 2. Technology of Mining and Preparation: Bureau of Mines Tech. Paper 713, 1951, 110 pp.

29/ See footnote 14.

30/ Buch, J. W., Allan, Andrew, Jr., and Davies, R. S., Anthracite Mechanical Mining Investigations. Progress Report 4. Status of Bureau of Mines Underground Experimental Work with Lightweight Shearing Machines in Pitching Anthracite Beds: Bureau of Mines Rept. of Investigations 4798, 1951, 11 pp.

Generated on 2024-09-20 11:11 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

compressed air as a source of power for the machines, reduced shattering of the coal surrounding the gangway as a result of the use of smaller explosive charges, and elimination of retimbering work caused by heavy blasting charges that are necessary in hand mining. Finally, mechanization permitted advance of an opening which was no wider than the coal bed and thus saved the removal and handling of large quantities of rock. The miners' tasks became less arduous because the coal mined was mechanically loaded. Roof support, which is the greatest time-consuming phase of this work, requiring 50 percent of the working time, is now the subject of an investigation with respect to increasing the miners' safety and the life of the support and decreasing the time required for its installation.

Investigations are in progress to measure the loads borne by underground roadway supports to obtain engineering data for use in connection with the design of a movable steel shield for driving coal gangways in pitching beds and, at the same time, to provide a sound engineering basis for the design of roof supports. Use of a shield in combination with the proposed supports is expected to increase the rate of advance of these gangways considerably, provide greater safety for the workmen, and reduce the time required to install the supports. An electrical instrument for measuring the required loads was designed and built. First underground tests were made, which proved the feasibility of the instrument. Work is now in progress for making the instrument fully permissible according to established Bureau of Mines standards.

Underground experimental work on a system of induced block caving for recovering coal in a 13-foot bed inclined at 75° is in progress at a mine in the Southern field. The slow, arduous work of driving breasts or slant chutes by existing methods in pitching beds, the loss of recoverable coal in the bed, and the ever-present danger of this type of work contribute considerably to the high cost of anthracite on the market and undoubtedly constitute influencing factors in forcing young men of the region to seek other employment. The Bureau, seeking corrective measures for this situation, is conducting tests on induced block caving in which a section of the coal bed is undercut and the solid coal drilled and blasted to a height of 10 to 15 feet. The coal blasted is loaded into cars by gravity, and as it is removed the remaining unsupported solid coal falls and is broken for loading without further labor. Definite conclusions will not be possible for a year or two, but results so far indicate a production rate nearly double that with conventional methods.

A complement of yielding-type steel props of German manufacture was received during the year and installed for initial test purposes in a 9-foot coal bed in the flat Northern field area. Although the work had been in progress only a few months, the possibilities offered are very promising. It was found that the yield point of 50 tons per prop are more than enough to carry the roof load in the pillar area already mined. Actually, the maximum load reached on props that were instrumented was 37 tons. This experiment must continue for perhaps 2 years before final conclusions can be reached.

Bituminous-Coal-Mining Studies

Studies were made of mine operations where pillars are extracted with mechanized equipment.[31] Conclusions from detailed studies of mining operations at more than 80 coal mines in all the important coal fields of the United States, were as follows:

31/ Haley, W. A., Shields, J. J., Toenges, A. L., and Turnbull, L. A., Mechanical Mining in Some Bituminous Coal Mines. Progress Report 6. Extraction of Pillars with Mechanized Equipment: Bureau of Mines Inf. Circ. 7631, 1952, 64 pp.

Generated on 2024-09-20 11:07 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

1. The open-end method of pillar extraction, the common method used, results in the highest percentage of recovery. The pocket-and-fender method is used widely also, but generally it does not provide as high recovery as the open-end method.

2. Mobile loading devices are most commonly used in the mines studied. Conveyor operations often obtain better recovery but generally lower performance in tons per man-shift than operations employing mobile loading equipment.

3. Overall recovery at mines where pillars are extracted ranges from 70 to 85 percent. Recovery in panels ranges from 75 to 95 percent. Recovery in mines where pillars are extracted ranges from 10 to 50 percent more than in mines operated under similar physical conditions but where pillars are not extracted.

4. The most difficult problem encountered in extracting pillars with mechanized equipment is effective control of not only the immediate roof but the entire overlying strata. Well-planned mining methods derived from extensive knowledge of pillar mining, as well as experience with local physical conditions, are essential.

5. The average labor employed underground, in man-hours per ton at mines where mobile loading devices are used, is greater and the average production per hour per mobile loading unit is less where pillars are extracted than where pillars are not extracted.

The Bureau of Mines, in cooperation with the Eastern Gas & Fuel Associates and with Mining Progress, Inc., experimented with a new type German coal planer mining coal on a longwall face in the 34-inch Pocahontas No. 4 coal bed, Stotesbury 11 mine, Helen, Raleigh County, W. Va. (figs. 4 and 5.). This was the first experiment in the United States with this type of mining machine.32/

The block of coal developed for the experiment was completely mined without leaving any pillars of coal. The roof was allowed to break and cave behind the coal by systematic manipulation of the steel roof supports and timber cribs. The block of coal was mined in 93 shifts and required 3,004 man-shifts to produce 51,450 tons of clean coal. As the recovery of clean coal from raw coal at this mine is 95 percent, the production of raw coal from the block was 54,158 tons or 18.0 tons per man-shift. The average production for developing the panel and mining the block of coal was 13.0 tons of raw coal per man-shift, as compared with 10.9 tons per man-shift by conventional mining as practiced at this mine. Machines to undercut coal before blasting and explosives to break coal preparatory to loading are used almost universally in room-and-pillar mining. Neither undercutting nor explosives to break the coal were needed for this equipment to load coal. A saving in other material costs was effected, particularly for mine props, as the steel props were used over and over again.

An analysis of changes in haulage equipment used underground in bituminous-coal mines from 1924 to 195033/ and data on types of haulage at bituminous-coal strip mines in 1948 and 194934/ were published. In 1949 bituminous-coal strip mines using trucks only handled 38 percent of the total output, mines using tractor

32/ Haley, W. A., Experiment With a German Coal Planer on a Longwall Face: Min. Cong. Jour., vol. 38, No. 6, June 1952, pp. 71-72; Abs. of paper presented at American Mining Congress in Cincinnati, Ohio, May 5-7, 1952.

33/ Young, W. H., and Anderson, R. L., Coal Haulage Underground: Min. Cong. Jour., vol. 38, No. 6, June 1952, pp. 40-41.

34/ Young, W. H., and Anderson, R. L., Haulage at Bituminous Coal Strip Mines: Mechanization, vol. 15, No. 7, July 1951, pp. 105-107.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:06 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

Digitized by Google

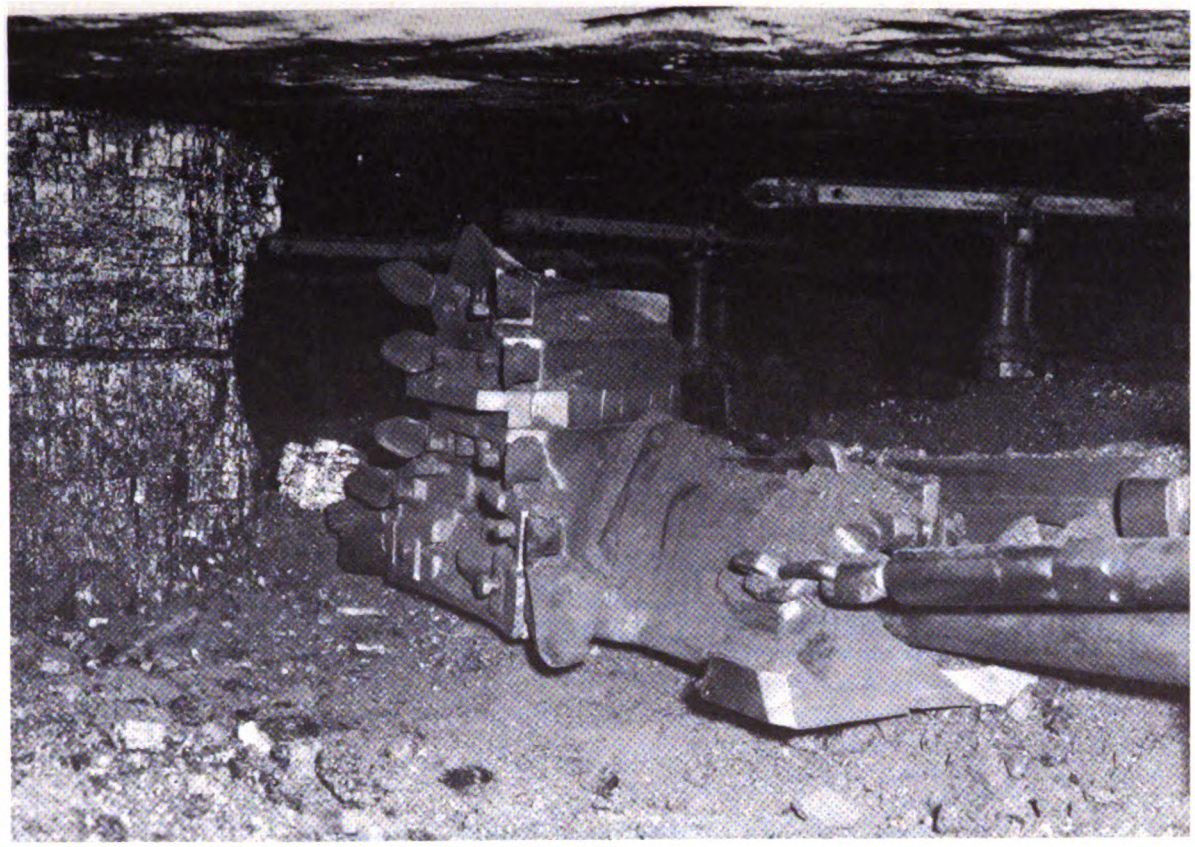

Figure 4. - German coal planer at Helen, W. Va.

Original from THE OHIO STATE UNIVERSITY

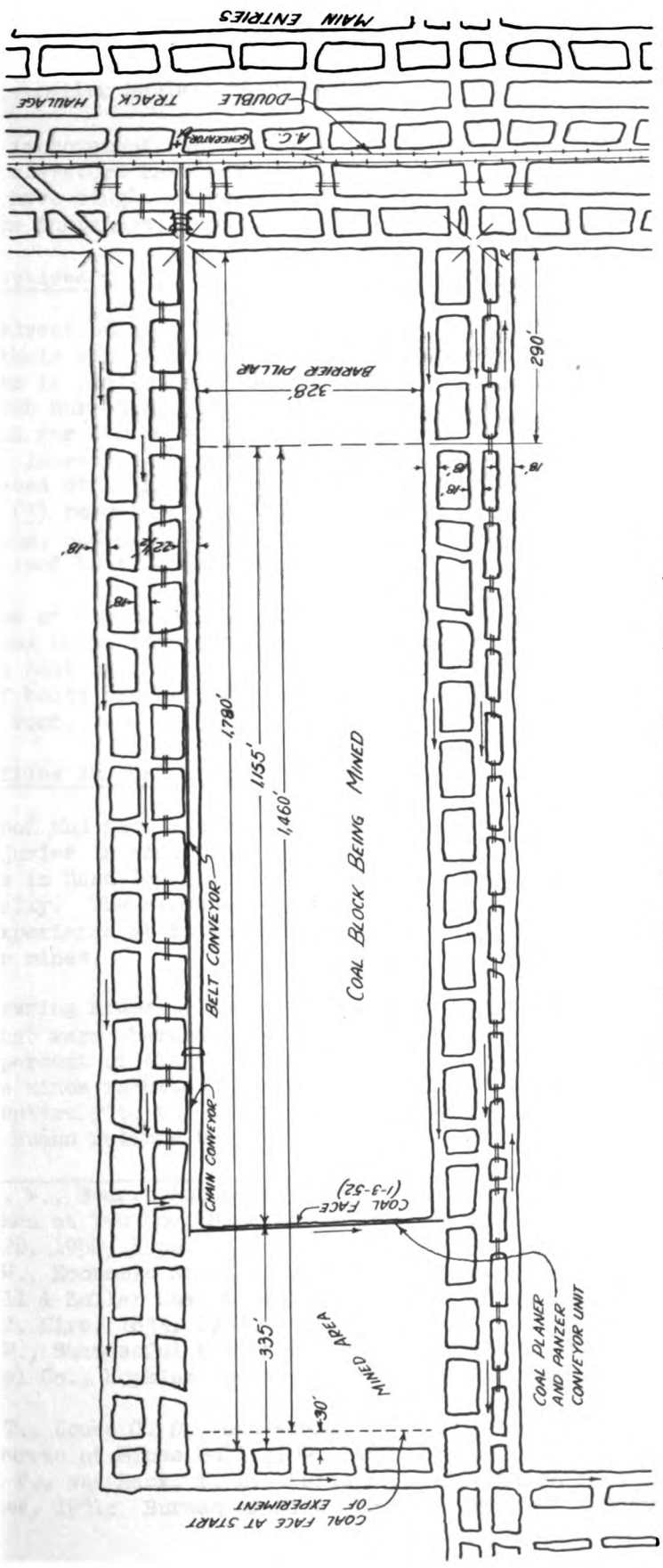

Figure 5. - Plan of experimental panel for planer.

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

trailers only handled 22 percent, mines using both truck and tractor trailers at the same mine handled 10 percent, and mines with rail or combination rail-and-truck or tractor-trailer haulage handled 5 percent.

Additional improvement was achieved at some mines where automatic electrically controlled elevators have been installed for transporting men in shafts.35/ These elevators have single or multiple decks and are primarily for transporting men; but, in some instances, supplies also are transported.

Roof-Bolting Practices

Since the advent of the first systematic installation of roof bolts in coal mines in 1947, their general adoption and use have become one of the most spectacular developments in coal-mining history. As an example of better procedure adopted in conformity with Bureau of Mines recommendations, a successful roof-bolting system was developed for a mine in Illinois.36/ Some of the benefits obtained in this mine were: (1) Increased tonnage per man-shift at the face when roof bolts are used; (2) increased efficiency of roof bolting by giving the foremen a definite plan to follow; (3) reduction in delays caused by failures of the trailing cables of loading, mining, and drilling machines; and, (4) reduction in the number of accidents after roof bolting was adopted.

Studies made of the material costs of roof bolting with steel and with wooden bolts at the Stony Point mine in Kentucky showed that cost of wooden bolts would be one-fifth of the cost of steel.37/ The Stony Point experience proved conclusively that wooden roof bolts can be used successfully under certain conditions and with a certain type of roof.

Causes of Fatalities in Coal Mines

Falls of roof and face caused over more than half the deaths and led as the cause of all injuries in coal mines in 1948; haulage was next in importance.38/ The injury rates in hand-loading mines were lower than in those where all coal was loaded mechanically. The average severity of all injuries was 154.5 days per injury. Injury experience at bituminous-coal mines was more favorable for larger than for smaller mines.

A study covering Federal investigation of 292 fatalities from falls of roof, face, and rib that were charged to the bituminous-coal industry during 195139/ showed that 50 percent of all the fatalities occurring underground at bituminous-coal and lignite mines resulted from falls of roof, face or rib, a decrease in percentage due entirely to the Orient disaster, which added 119 men to the total number killed. Human failure was responsible for 80 percent of the fatalities.

35/ Holcomb, J. W., Modern Automatic Electrically Controlled Elevators for Transporting Men at Two Coal Mines in Western Pennsylvania: Bureau of Mines Inf. Circ. 7628, 1952, 5 pp.

36/ Kelly, L. W., Economic Benefits of Systematic Roof Bolting in Zeigler No. 3 Mine, Bell & Zollar Coal & Mining Co., Williamson County, Ill.: Bureau of Mines Inf. Circ. 7633, 1952, 9 pp.

37/ Kelly, L. W., Successful Use of Wooden Roof Bolts in Stony Point Mine, Stony Point Coal Co., Hopkins County, Ky.: Bureau of Mines Inf. Circ. 7637, 1952, 4 pp.

38/ Moyer, F. T., Jones G. D., and Wrenn, V. E., Injury Experience in Coal Mining, 1948: Bureau of Mines Bull. 509 1952, 109 pp.

39/ Weaver, H. F., and Back, T. L., Falls of Roof, The No. 1 Killer at Bituminous-Coal Mines, 1951: Bureau of Mines HSS 406, Mineral Industry Surveys, 1951, 10 pp.

Generated on 2024-09-20 11:07 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Measures recommended to prevent such injuries and deaths included: (1) Adoption and observance of minimum standards for roof support at each mine, (2) training foremen and miners in safe practices in roof support, (3) regular examination of overhanging surfaces, (4) adoption of roof bolting where its feasibility has been shown, and (5) elimination of the practice of removing permanent timbers by hand.

Investigation and study of 165 haulage fatalities during 1951 and 6 months of 1952 covered occurrences in 13 coal-producing States.40/41 The victims were killed in many different ways. The most frequent were: Caught by moving equipment; contacted low roof or crossbars; injured by runaway equipment; collisions; and squeezed between haulage equipment and a timber leg, coal rib, or the face.

Specific recommendations were made to overcome hazards and operating practices that contribute to recurring injuries in using shuttle cars.42/

The practice of firing open, unconfined shots is not uncommon in coal mines, despite the fact that numerous mine explosions and dust ignitions have resulted. A study of Bureau of Mines records showed that 6 major disasters have been caused by the firing of open, unconfined shots of the bulldozing type during the past 24 years.43/

Circuit-Breaker Protection in Coal Mines

Serious fires have occurred in bituminous-coal mines because of short circuits on direct-current power systems that do not have adequate circuit-breaker protection. Faulty protection results in fire hazards that endanger lives and property. Proper circuit-breaker protection would greatly minimize or, in many instances, eliminate the hazards; moreover, many operating advantages of proper application of modern circuit breakers would be gained. Tests of effectiveness of circuit-breaker protection were made in four coal mines.44/ The mines were selected to illustrate both proper and improper breaker protection against short circuits. Results of the tests pointed to the necessity of adequate circuit-breaker protection on 250/275-volt d.c. systems.

Mine Atmospheres

In connection with the Bureau's program of coal-mine inspection, approximately 14,000 samples of mine air were analyzed to determine the adequacy of ventilation in coal mines, to detect and aid in eliminating hazards from flammable and toxic gases in mines, to aid in controlling and extinguishing mine fires, and to provide information on various other matters pertaining to health and safety in coal mining.

Surveys were conducted in coal mines to determine the concentrations of airborne dust produced by various mining operations, with particular emphasis on the

40/ Ankeny, M. J., and Kingery, D. S., Haulage Fatalities in Bituminous Coal Mines: Bureau of Mines HSS 405, Mineral Industry Surveys, 1951, 15 pp.; HSS 408, January-June 1952, 17 pp.

41/ Ankeny, M. J., and Kingery, D. S., Analysis of Haulage Fatalities in Coal Mines, January-June 1951: Bureau of Mines Inf. Circ. 7622, 1951, 14 pp.

42/ Kingery, D. S., Recommendations for Improved Shuttle-Car-Haulage Safety: Bureau of Mines Inf. Circ. 7638, 1952, 10 pp.

43/ Ankeny, M. J., Hazard of Firing Open, Unconfined Shots in Coal Mines: Bureau of Mines Inf. Circ. 7632, 1952, 4 pp.

44/ Gallagher, F. J., Minimizing Fire Hazards in Coal Mines by Proper Circuit-Breaker Protection of 250/275-Volt Direct-Current Systems: Bureau of Mines Inf. Circ. 7624, 1951, 11 pp.

Generated on 2024-09-20 11:09 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

investigation of dust produced by drilling for roof bolting and in other rock-drilling operations. In addition to determination of dust concentrations to which drillers were exposed, the free-silica contents of the strata drilled were determined by X-ray diffraction to evaluate the potential silicosis hazard involved. Special attention was given to the study of the dust problem attending the drilling of coal-mine roof for inserting roof bolts.45/46/47/

The results of infusion of coal pillars with water or water mixed with a wetting agent showed conclusively that much air-borne dust created and released normally during mining, especially during extraction of the pillars on retreat can be suppressed at its source by this method.48/

A schedule of approval requirements for dust collectors for use in connection with rock drilling in coal mines was prepared,49/ and approval testing was begun on three collectors submitted under the provisions of the schedule. Data obtained several years ago on the size of drill cuttings produced by different types of drill bits were analyzed.50/

A description of ventilation practices used in some bituminous-coal mines selected by Bureau engineers as good examples and other nontechnical information pertinent to safe mine-ventilating systems was made available as a text and reference for use of mine employees and mine officials.51/

Approximately 1,000 examinations were conducted to determine the concentration and particle size of air-borne dusts, and the composition of such dusts and dust source materials to evaluate their hygienic significance in the working environment of coal and other types of mines. These examinations were conducted by microscopic, petrographic, X-ray diffraction, and spectrographic methods. Examinations were made also of various materials to determine their suitability for use in rock dusting coal mines.

Approval testing was conducted on respiratory protective devices, including gas masks and dust respirators applicable to use for personal protection in coal

---

45/ Westfield, James, Anderson, F. G., Owings, C. W., Harmon, J. P., and Johnson, Leslie, Roof Bolting and Dust Control: Bureau of Mines Inf. Circ. 7615, 1951, 8 pp.

46/ Westfield, James, and Anderson, F. G., Hazards of Roof Bolting: Coal Mining, vol. 29, June 1952, pp. 10-12, 14.

47/ Westfield, James, Roof Drilling With Dust-Control Equipment: Proc. Illinois Min. Inst., 1951, pp. 21-29.

48/ Jackson, E. O., and Merritts, W. M., Water Infusion of Coal Pillars Before Mining, Kenilworth Mine, Independent Coal & Coke Co., Kenilworth, Utah: Bureau of Mines Rept. of Investigations 4836, 1951, 25 pp.

49/ Bureau of Mines, Procedure for Testing Dust Collectors for Permissibility for Use in Connection with Rock Drilling in Coal Mines: Code of Federal Regulations, Title 30, chap. 1, subchap. E, part 33, Federal Register, vol. 17, No. 25, Feb. 5, 1952, pp. 1118-1121. (Designated as Bureau of Mines Sched. 25.)

50/ Brown, C. E., Size of Cuttings Produced by Pneumatic Drilling with Different Kinds of Detachable Bits: Am. Med. Assoc. Arch. Ind. Hyg. and Occup. Med., vol. 4, August 1951, pp. 103-118.

51/ Artz, R. T., Some Practical Aspects of Coal-Mine Ventilation: Bureau of Mines Handbook, 1951, 45 pp.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

mines and other mineral industries.52/53/ Three new approvals and 25 extensions of approvals were granted, representing modifications and improvements in design.

Anthracite Flood Prevention

To have a sound foundation upon which an engineering study of the anthracite mine-water problem could be based, it was necessary to gather factual data on the quantities of water impounded in abandoned as well as active mines, the quantities of water being pumped from each mine, condition of barrier pillars restraining water in abandoned mines or serving as protection for active workings, the extent and depth of the glacial deposits overlying the coal measures in the Northern field, and the character of the mine water and surface streams thereby affected. It appears that both a short-range and a long-range solution of the anthracite mine-water problem can be best served by a gravity-tunnel system, consisting of a main tunnel and two or more main central pumping plants for emergency use. The main tunnel would convey the water to a point near tidewater outside the anthracite region. The mine water would be collected at its source and conveyed to the main tunnel by a network of lateral and sublateral tunnels.54/ The information obtained by examining and analyzing the core drillings from 15 diamond-drill holes shows that, with proper equipment, little difficulty should be experienced while sinking the shafts at the 15 selected sites. Although a number of holes penetrated formations containing a high percentage of silica, the health hazard from dust can be removed by using proper dust-control equipment.

PREPARATION OF COAL

Coal Washing

Prediction of Washery Performance

Coal-preparation engineers frequently must forecast the yield and ash content of the washed coal to be expected in a new washing operation, either in connection with the design of a new plant or in planning the treatment of a new coal in an existing washery. Yield and quality of washed coal are factors of prime economic importance in any washing operation, hence their accurate prediction is essential. It has been found that relatively simple engineering calculations can take the guesswork out of predicting washery performance if the necessary basic data are available.55/ The information required is complete performance data on the washing unit involved and a float-and-sink test of the new coal.

The method of predicting yield and ash content is based on the use of a type of plot called a "distribution curve," which is illustrated in figure 6. The distribution curve is simply a plot showing what percentage of each density fraction of the raw coal was recovered in the washed product and what percentage was rejected as refuse. This information is provided by float-and-sink tests of the

52/ Pearce, S. J , What Is an Approved Respirator?: Safety Maintenance and Production, vol. 103, January 1952, pp. 30-32, 47.

53/ Pearce, S. J., and Berger, L. B., List of Respiratory Protective Devices Approved by the Bureau of Mines: Bureau of Mines Inf. Circ. 7636, 1952, 16 pp.

54/ Ash, S. H., Doherty, R. Emmet, Miller, P. S., Romischer, W. M., and Smith, J. D , Core Drilling at Shaft Sites of Proposed Mine-Water Drainage Tunnel: Anthracite Region of Pennsylvania: Bureau of Mines Bull. 513, 1952, 43 pp.

55/ Geer, M. R., How to Predict Results of Washing a New Coal: Coal Age, vol. 57, no. 6, 1952, pp. 96-97.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

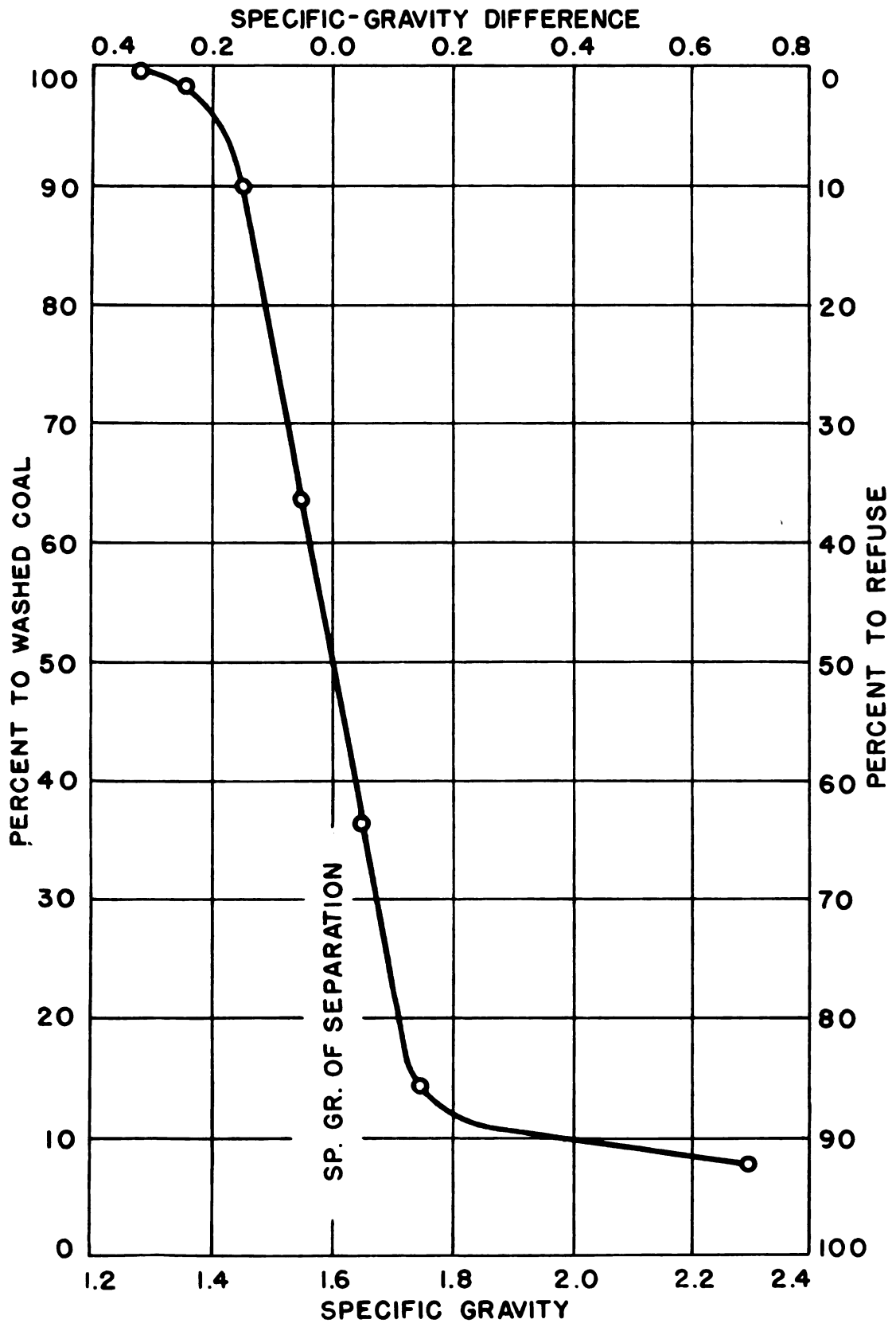

Figure 6. - Distribution curve for Baum-type jig.

Generated on 2024-09-20 11:10 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from
THE OHIO STATE UNIVERSITY

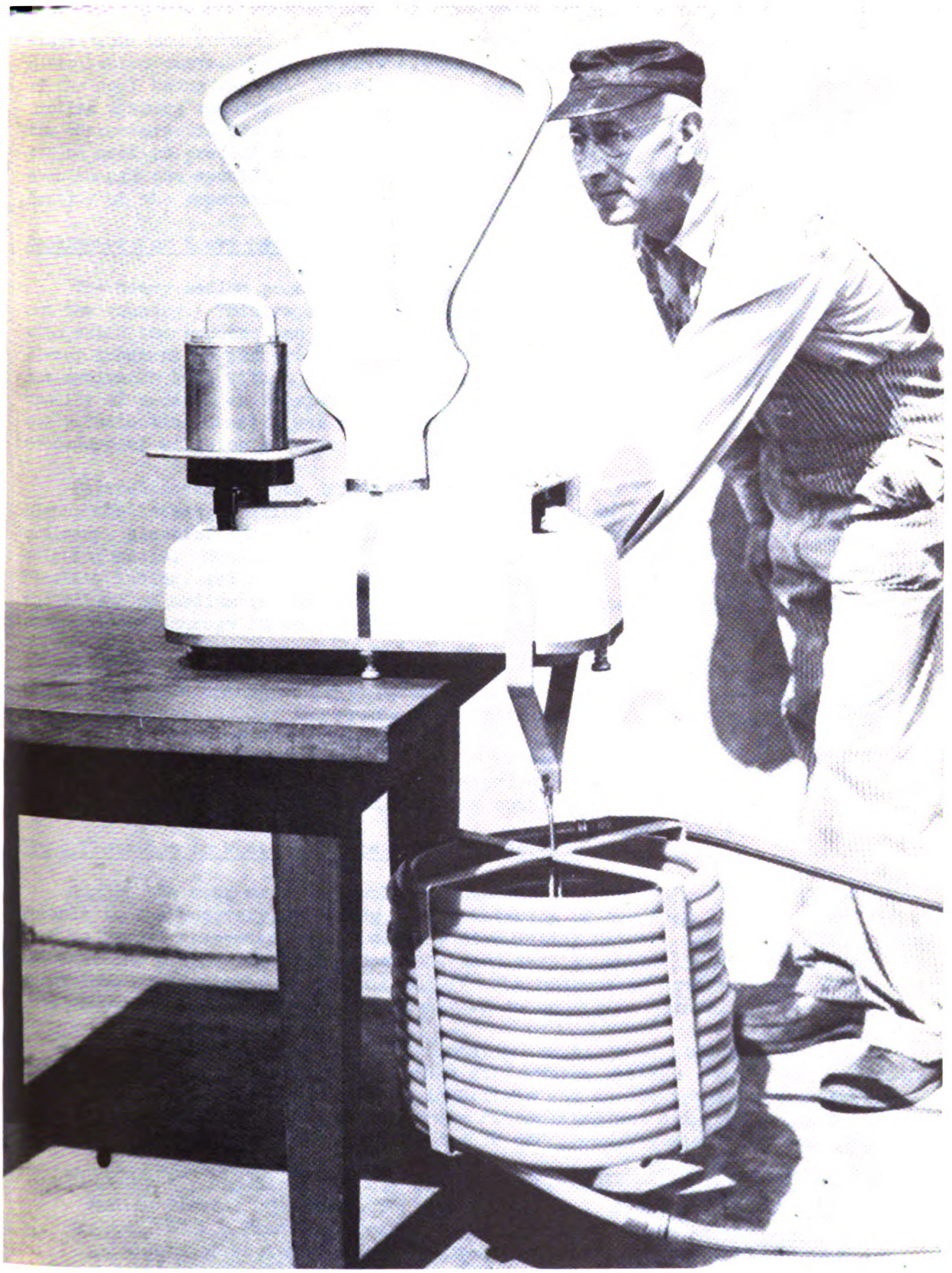

Figure 7. - Densimeter for continuously indicating density of heavy medium.

Generated on 2024-09-20 11:09 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

washed coal and refuse. Each type of washing equipment has its own characteristic distribution curve, which is substantially independent of the density composition of the coal being washed. On this point rests the usefulness of the curve in predicting washing results. Once float-and-sink tests on the products have indicated the characteristic distribution curve for a given type of washing unit, the curve can be used to predict accurately the results of washing another coal in the unit, even though the specific-gravity composition of the new coal is different and the density of the separation required is either higher or lower.

Densimeter for Heavy-Medium Plants

The heavy-medium process for cleaning coal is being used increasingly throughout the country. This rapid growth is attributable largely to the greater sharpness with which the process can separate coal from impurity. However, the high efficiency inherent in the process cannot be achieved completely unless the density of the medium is kept within very narrow limits. To assist in maintaining constant density of medium, an inexpensive, simple, but highly accurate device for continuously indicating density was developed to replace the cumbersome, time-consuming procedure of weighing a known volume.56/

Several models of the densimeter were built and used in the Bureau's pilot plant; the latest is illustrated in figure 7. In this model a 50-foot coil of ordinary, plastic, 3/4-inch garden hose is suspended from a sensitive, commercial weighing scale. Medium from the plant circuit enters the hose through a length of flexible tubing, and returns to the circuit through a similar connection. Since the volume of medium in the hose is constant, any change in density produces a corresponding change in weight.

Hundreds of check determinations were made between the density indicated by the densimeter and that found by weighing a calibrated flask of medium. The average deviation was 0.001; the greatest deviation was 0.004. The accuracy of the densimeter is thus more than ample for either plant or laboratory use. Only one primary precaution needs to be observed in using the densimeter: A pressure drop of over 5 p.s.i. through the hose must be provided to insure a velocity of flow sufficient to keep magnetite from settling out.

Froth Flotation in Western Europe and Great Britain

One of the most serious problems connected with modern coal-preparation methods is the recovery, cleaning, and dewatering of the fine sizes of coal that tend to become suspended in the washery circulating water. As one solution to this problem, the froth-flotation process is used very extensively in some European countries, particularly Great Britain.57/ The process is used to some extent in this country also but not as extensively as in countries abroad.

Cost data are tabulated for the flotation sections of some of the plants, and reference is made to the most noticeable differences between trends abroad and in this country, particularly the trend in Britain and Europe toward closed water circuits in which the flotation tailings are flocculated and clear overflow water is returned to the circuit. Another noticeable difference is the almost universal

56/ Olds, W. A., and Klein, M. J., Dependable Densimeter Developed for Heavy-Medium Plants: Mechanization, vol. 16, No. 6, 1952, pp. 126-127.

57/ Gandrud, B. W., Fraser, Thomas, and Yancey, H. F., Froth Flotation Practice in Plants of Western Europe and Great Britain: Bureau of Mines Rept. of Investigations 7614, 1951, 17 pp.

Generated on 2024-09-20 11:14 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

European and British practice of using coal-tar products as flotation reagents instead of the petroleum oils and pine oil employed so extensively in this country.

Preparation Characteristics of Coking Coals

In an investigation of the preparation characteristics of coal that might be available for production of metallurgical coke, a survey initiated in 1950 was continued in four counties that produce coal available to the steel industry in western Pennsylvania. Reports were published that cover in detail the preparation characteristics of the principal coal beds in each of these counties. The main washing problem concerns the release of sulfur from the coal.

Clearfield County, Pa.

In Clearfield County[58] the important coal reserves are medium volatile and are in the Upper Freeport, Lower Freeport, Upper Kittanning, Middle Kittanning, Lower Kittanning and Brookville beds. The Middle Kittanning and Brookville beds are high-sulfur deposits and cannot be considered suitable sources of coal for metallurgical coke. The Upper Freeport bed is rather thin, usually less than 3 feet thick, but persists over much of the county. The sulfur in the bed is not excessive, and the cleaned coal is a low-sulfur product. The Lower Freeport bed in southern Clearfield County will yield, without difficulty, a suitable metallurgical-grade coal. As the deposit extends to the northern part of the county sulfur and volatile matter increase, and preparation of a satisfactory coking coal would require fine crushing and probable separate disposal of a middling product. The Upper Kittanning bed, although too thin in many places to support mining and usually contaminated by many partings and binders, is responsive to mechanical cleaning and will yield a low-sulfur washed coal. The Lower Kittanning bed is an important source of coal in the southeast portion of Clearfield County. Here the bed can be upgraded to metallurgical use by easy washing, except where the bed contains a top bench of bone coal that is indicative of high sulfur. Sulfur and volatile matter increase as the bed extends northward, and samples collected close to the Clearfield-Elk County line contained too much sulfur to be considered as sources of coking coal.

Fayette County, Pa.

In Fayette County[59] the principal coal reserves are in the Sewickley, Redstone, Pittsburgh, Upper Freeport, Lower Freeport, Upper Kittanning, Lower Kittanning, and Clarion beds. The importance of the Pittsburgh bed has retarded development of other beds in Fayette County, especially those underlying the Pittsburgh. The approaching exhaustion of the Pittsburgh bed will require accelerated exploitation of these thinner beds. The Sewickley bed is an important potential source of steam coal. The bed is as much as 6 feet thick and easily accessible. The excessive quantities of sulfur, much of which is not removable by mechanical cleaning, makes the Sewickley bed unsuitable for metallurgical use. A metallurgical coal can be prepared from the Redstone bed by carefully controlled washing. At some places fine crushing would have to be employed to release the sulfur. The Pittsburgh bed was not studied in this report as its adaptability for use in the coke industry has long been recognized. The Upper Freeport bed contains the largest coal reserve in the county.

58/ Crentz, W. L., Bailey, A. L., and Miller, J. W., Preparation Characteristics of Coal from Clearfield County, Pa.: Bureau of Mines Rept. of Investigations 4894, 1952, 27 pp.

59/ Crentz, W. L., Bailey, A. L., and Miller, J. W., Preparation Characteristics of Coal from Fayette County, Pa.: Bureau of Mines Rept. of Investigations 4815, 1951, 16 pp.

Generated on 2024-09-20 11:08 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The bed varies widely in thickness and quality. Float-and-sink tests showed the possibility of preparing a coal for metallurgical-grade coke from the bed with moderate difficulty in the northeast portion of Fayette County. Sulfur in the coal appears to increase as the bed extends southward, and it is doubtful that the Upper Freeport bed could be upgraded to metallurgical standards over a wide area. Preparing a clean coal containing 1.25 percent sulfur from the Lower Freeport bed does not appear possible, except by fine crushing and separate disposal of substantial amounts of high-sulfur dust produced during crushing. A washed coal containing 1.40 percent sulfur could be obtained from the Lower Freeport bed without crushing, thereby eliminating the need for economic utilization of a high-sulfur dust. The Upper Kittanning bed in Fayette County will not yield a low-sulfur washed coal. A clean coal containing about 1.50 percent sulfur can be obtained by easy washing. The Lower Kittanning bed has been mined extensively in the northeast corner of Fayette County. Here a low-sulfur washed coal can be achieved by fine crushing. As the bed extends southward the problem of upgrading the coal to metallurgical standards becomes increasingly difficult. The Clarion bed is mined to a limited extent in Fayette County, but excessive sulfur in the washed coal eliminates this deposit from consideration as a possible source of metallurgical coal.

Somerset County, Pa.

Somerset County[60] contains one of the largest reserves of low-volatile bituminous coal in Pennsylvania. The principal reserves are in the Upper Freeport, Lower Freeport, Upper Kittanning, and Lower Kittanning beds, with the Sewickley, Pittsburgh Rider, Pittsburgh, Clarion, and Brookville, beds of secondary importance. The Sewickley-bed reserves are limited, and the bed usually contains a top bench of bony coal, which, when left in place, will permit extraction of a low-sulfur product. The Pittsburgh bed has been almost entirely exhausted in the more favorable mining locations. Where the bed is still mined, it is usually divided into two benches. The bottom bench is inferior in quality, and unless it is kept separate from the top bench during washing the problem of preparing a low-sulfur metallurgical coal becomes difficult. The Upper Freeport, Lower Freeport, Upper Kittanning, and Lower Kittanning coals usually can be upgraded to meet metallurgical standards. When the raw coal is high in sulfur it must be finely crushed to release the sulfurous impurities. The Clarion bed is usually mined in Somerset County to supply a local demand. It is a high-sulfur deposit and cannot be used as a source of coal for producing metallurgical coke.

Westmoreland County, Pa.

In Westmoreland County[61] the principal coal reserves are in the Pittsburgh and Upper Freeport beds. Reserves of minor importance are found in the Redstone, Lower Freeport, and Lower Kittanning beds. When the total sulfur in the Redstone bed exceeds 2 percent, preparation of a low-sulfur metallurgical fuel containing 1.25 percent or less sulfur is unlikely. The Upper Freeport bed contains the largest reserve in Westmoreland County, and accelerated exploitation of the bed is taking place as the high-quality Pittsburgh bed becomes depleted. The bed is marked by extreme variability in thickness and quality. At some places the bed contains less than 1 percent sulfur, whereas elsewhere fine crushing and precise control of

---

60/ Crentz, W. L., Bailey, A. L., and Miller, J. W., Preparation Characteristics of Coal from Somerset County, Pa.: Bureau of Mines Rept. of Investigations 4834, 1951, 23 pp.

61/ Crentz, W. L., Bailey, A. L., and Miller, J. W., Preparation Characteristics of Coal Occurring in Westmoreland County, Pa.: Bureau of Mines Rept. of Investigations 4823, 1951, 17 pp.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

washing must be utilized to prepare a satisfactory metallurgical fuel. The Lower Freeport bed will not yield a low-sulfur washed coal, but fine crushing and careful cleaning will produce a washed coal containing about 1.50 percent sulfur. The Lower Kittanning bed is a low-volatile deposit in the northeast corner of Westmoreland County, where the coal outcrops along the Conemaugh River. Here the coal is responsive to mechanical cleaning for preparation of a metallurgical fuel. As the bed extends westward along the Conemaugh River, volatile matter and sulfur increase. Coal in this area is unsuited to the preparation of a coking coal because of excess sulfur in the float coal.

Briquetting Coal and Char

Briquetting of fine coal and char, long practiced as a means of disposing of fine sizes of fuels, is finding new application in the solution of special fuel problems. Two of these on which the Bureau is conducting research are: (1) The production of a stable, storable fuel for use by the armed forces in Alaska and (2) the development of a charcoal substitute in such areas as Mexico.

Alaskan Coals and Chars

The cost of importing fuel from the States to Alaska in sufficient quantities would be excessive. However, large reserves of Alaskan subbituminous coal are available for use. This low-rank, high-moisture coal can be mined only in summer. It can be stored, but only by means that destroy its usefulness as a hand-fired domestic fuel. In addition, the raw coal as mined is too smoky for satisfactory use in the space heaters normally used for heating barracks. Progress is being made on developing suitable briquets that can be produced from available Alaskan coal.

The coal is first dried and then carbonized to produce a moisture-free, medium volatile, smokeless char. This char is very reactive and ignites easily. It can be produced either by drying and carbonizing fine coal in the fluidized systems developed by the Bureau or by carbonizing the lump coal in special retorts. Tar is obtained as a byproduct from coal carbonization, and this tar can be distilled to produce pitch. This pitch is then used as the binding material for briquetting the fine char. Other available binders, such as starch and sulfite liquor, a byproduct from kraft-paper manufacture, are also being studied.

The research is now being pointed toward selection of the carbonizing, binding, and briquetting techniques that will provide the most satisfactory product, taking into account the cost, smokiness, ease of ignition, and storing properties of the briquets.

Mexican Coals

The Mexican problem has arisen because of depletion of forests in an area that traditionally has used wood charcoal as a domestic fuel. Charcoal is burned in that country in open fires inside the houses and is used because it is odorless and smokeless and ignites easily. Although several ranks of coal are available in Mexico, they do not have these properties and cannot be used by the established practice. In cooperation with the Mexican Government, through the Bank of Mexico, the Bureau is studying the processing and briquetting of Mexican coals to produce a satisfactory charcoal substitute.

The reserves and availability of the various ranks of Mexican coals are being determined by the Mexican Government. The Bureau is studying two of the more promising bituminous coals, but it is hoped that supplies of lower rank coals, subbituminous or lignite, can be found. Briquets made from the coals being studied are

Generated on 2024-09-20 11:14 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:17 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

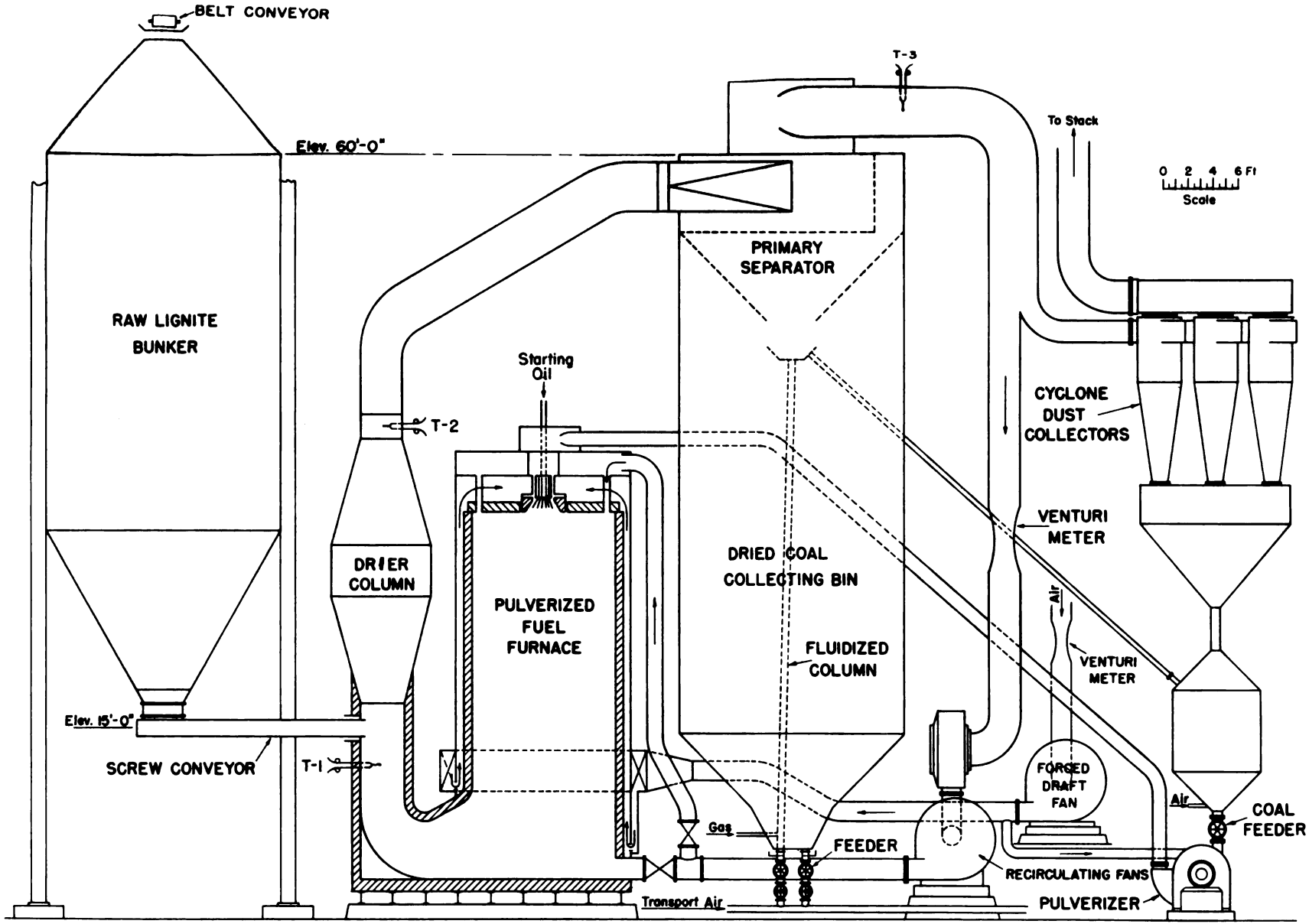

Figure 8. - Schematic Engineering Design of 50-ton per hour fluidized drying unit for lignite.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

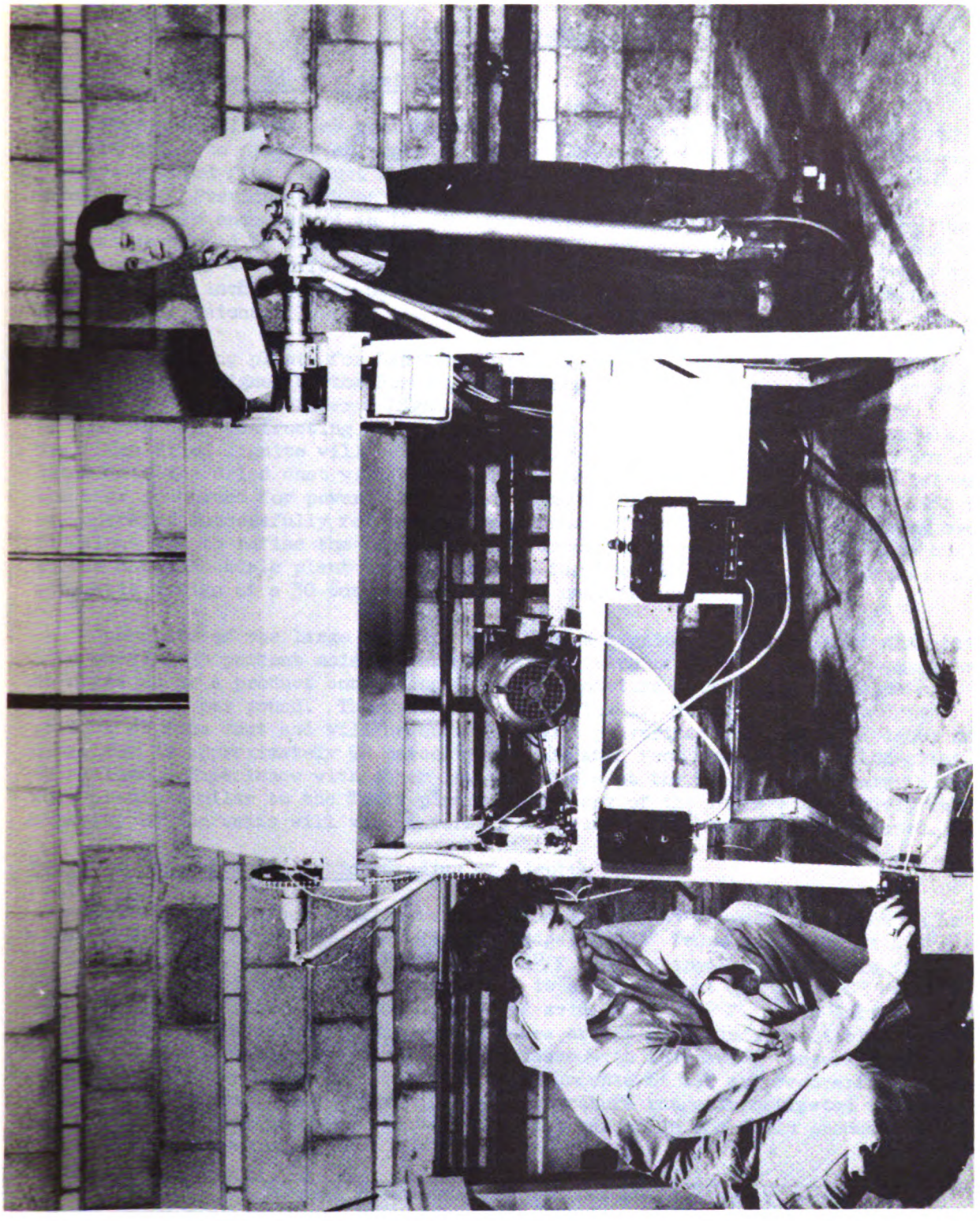

Figure 9. - Apparatus for thermal treatment of North Dakota lignite at controlled temperatures.

Generated on 2024-09-20 11:18 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from
THE OHIO STATE UNIVERSITY

promising, but it appears that the raw coals will have to be cleaned to reduce their sulfur and ash contents before a satisfactory briquet can be produced from them.

Drying Low-Rank Coals

Drying of Lignite and Subbituminous Coal

Experimental work was continued on drying Texas lignite and other low-rank western coals to produce an upgraded fuel suitable for power plant use and also to prepare a dried fine product suitable for carbonization in the entrained and fluidized state. Previous work on drying fine coal at the Denver laboratories had shown that any fuels encountered in the Western States can be dried effectively by the new process developed by the Bureau of Mines, and 90 to 95 percent of the inherent moisture and all of the surface moisture can be removed by this method when coals of less than 3/8 inch size are handled. Further work during 1952 confirmed these earlier conclusions.

Large drying plants for handling Texas lignite at capacity up to 1,200 tons per day were designed by the Bureau, and 1 large pilot model was constructed and operated by the Texas Power & Light Co., which is agent for the Aluminum Co. of America in constructing and operating a 300,000-kw. power plant at Rockdale, Tex. The dried lignite will be used initially to operate the power plant, but at a later date the dried dust will be carbonized to remove valuable crude tars before the char is burned for power. The first large drier was completed in June 1952 and was operated successfully for several weeks thereafter to develop engineering specifications and to refine the process. Nine driers of improved design will be built at the ALCOA Rockdale plant to provide fuel for the 300,000-kw. power plants. A schematic design of a 50-ton-per-hour drying unit is shown in figure 8.

Operation of the large pilot plant on Texas lignite has proved that this lignite, having 35 percent moisture and a heating value of 7,000 B.t.u. per pound, can be upgraded to a product containing 5 percent moisture with a heating value of 10,000 B.t.u. per pound. The fuel used for drying is extracted from the dried product as fine dust and will be burned without pulverization. The efficiency of operation is approximately 92 percent, as indicated from the smaller pilot-plant operations. Experience with other low-rank fuels at the Denver laboratory indicates that plants similar to the Texas plant can dry any of the fuels encountered, but the capacity of the units will vary inversely with the amount of moisture removed.

Moisture Removal and Sorption Studies of Lignite

Moisture and carbon dioxide removal from lignite by thermal treatment in an electrically heated rotary drier was investigated.62/ Tests were made at 250°, 300°, 400°, 500°, 600°, 700°, 850°, and 950° F. in the apparatus shown in figure 9. The results showed that: (1) The moisture is eliminated at 300° to 400° F.; (2) appreciable quantities of carbon dioxide is evident at 400° F. which increases with increasing temperature; (3) hydrocarbon gases are released in appreciable amounts, beginning at approximately 600° F. and increase with increasing temperature; (4) beginning slightly below 700° F., increasing amounts of tar are recovered with increasing temperature; and (5) within the temperature range investigated there is a continuous increase in the percentage of total carbon in the solid product with increasing temperature.

62/ Oppelt, W. H., Thermal Treatment of North Dakota Lignite at Controlled Temperatures: Proc. North Dakota Acad. Sci., vol. 6, 1952, pp. 36-38.

Generated on 2024-09-20 11:14 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Previous experiments have indicated that lignite dried to low moisture contents resorbs moisture readily from the air until an equilibrium moisture content is established, depending upon the relative humidity and the treatment the lignite has undergone. To establish the influence of thermal treatment upon the sorption characteristics of lignite, representative samples of North Dakota lignite from the Kincaid mine were heated at temperatures ranging from 250° to 950° F. and placed in a specially constructed humidity cabinet until an equilibrium weight was established at a relative humidity of about 90 percent.63/ A sample of gasification residue, which had undergone exhaustive steam treatment at elevated temperature, was also hydrated. The major conclusions drawn from these experiments were as follows: (1) The equilibrium moisture content of the hydrated lignite at constant humidity is inversely related to the treating temperature; (2) analysis of the results as a function of the treating temperature indicates that rather abrupt changes in moisture sorption occur at treating temperatures, which lead to changes in the structure of the lignite; (3) the rate of hydration of lignite treated at 400° F. or above is inversely related to the treating temperature; and (4) exhaustive steam treatment increases the sorptive power of lignite char.

TRANSPORTATION AND STORAGE OF COAL

Hydraulic Transportation

An extensive survey was made to determine the feasibility of hydraulic transportation of coal, both from the standpoint of available operable equipment in similar services and from the angle of construction and operating costs.64/65/ It was concluded that coal can be transported economically by pipeline.

An estimate of costs was made on the construction and operation of a 100-mile long level coal pipeline based on 800-foot head between each pumping station, an efficiency of 65 percent for coal pumps and 80 percent for water pumps, and with dual lines laid under ground. The results indicate the following cost ranges:

Coal, tons per day	Construction cost, $1,000,000	Transportation cost, $ per ton per 100 miles
5,000	9.3 - 10.1	1.28 - 1.91
7,000	10.3 - 11.9	1.09 - 1.77
12,000	12.3 - 14.0	.73 - 1.24
24,000	16.4 - 19.1	.50 - .88
36,000	18.9 - 25.7	.38 - .95

A summary of references on this subject is included in the published paper.

Storage of Lignite

In connection with the lignite-processing plant being constructed in Texas, it is necessary to provide emergency supplies of fuel to insure continuous operation of the power plant. The Bureau of Mines is providing technical advice and supervision to insure safe storage of the large quantities of fuel involved. The techniques

63/ Kube, W. R., Sorption of Water Vapor by Thermally Treated North Dakota Lignite: Proc. North Dakota Acad. Sci., vol. 6, 1952, pp. 83-85.

64/ Dougherty, R. W., A Survey on the Hydraulic Transportation of Coal: Bureau of Mines Rept. of Investigations 4799, 1951, 22 pp.

65/ Dougherty, R. W., Coal Pipeline Transportation: Proc. 4th Conf. Coal Research, Inc., Centralia, Wash., Dec. 7 and 8, 1951, pp. 27-32.

Generated on 2024-09-20 11:16 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

employed are those developed and proved by the Bureau in connection with the storage of lignite for the Corps of Engineers at Garrison Dam, N. Dak. To date, approximately 320,000 tons of lignite, salvaged from the proposed cooling lake site, is being stored at the Texas operation. The completed storage pile will contain 600,000 tons of lignite. Temperature and gas-analysis surveys are conducted periodically by Bureau personnel, and these have indicated that the pile was properly constructed.

In the course of building the installations at Garrison Dam, N. Dak., the Corps of Engineers will uncover and move approximately 5,000,000 tons of lignite. This project has been under way for 5 years, and to date approximately 850,000 tons of lignite have been placed in storage by the above method. Bureau personnel is also making periodic studies of this storage, and the results indicate that lignite can be stored safely for an indefinite period when proper precautions are taken.

To assist industrial users of lignite with their storage problems storage conditions and practices at various power and heating plants in the Grand Forks, Crookston, and Fargo areas of North Dakota were inspected. Recommendations as to the proper storage methods were given when required.

Two 400-pound samples of Dakota Star lignite from North Dakota dried at 400 p.s.i. were stored outside in wire-mesh containers for 834 days. Sample 1 had been sized 3/4- by 1-1/2-inch, and sample 2 was sized 1/4- by 1/2-inch. During storage, the moisture content of sample 1 increased from 12.4 to 15.8 percent, whereas the moisture content of sample 2 increased from 10.0 to 16.3 percent, indicating that the factor of size is unimportant as far as the equilibrium moisture content is concerned. The heating value of sample 1 on a moisture- and ash-free basis decreased slightly from 12,020 to 11,750 B.t.u. per pound, a reduction of only 1 percent per year. The variation in heating value of sample 2 was less than the experimental error of the determination. The smaller sizes may prevent air circulation through the stored material, thus reducing the loss of heat value during storage. Visual inspection of the storage containers indicated that the dried lignite slacked only on the outside, whereas the lignite in the interior of the container was still in good condition.

UTILIZATION OF COAL AND OTHER FUELS FOR COMBUSTION

Fuel-Engineering Service

Consulting and field-testing services to aid Federal agencies in selecting, testing, and using fuel and fuel-burning equipment and in the economical use of steam were continued. Services on 152 special problems were given 42 different Federal agencies.

In addition, a series of acceptance tests for the Bureau of Indian Affairs was made on new boiler and turbine-generator equipment of the Navajo Agency, Shiprock, New Mex., power and heating plant. These tests revealed that a number of changes to the boiler and stoker equipment were necessary to satisfy contract requirements; after changes were made, smoke emission was effectively reduced, and future savings in annual fuel costs of $5,000 were indicated. At the request of the Public Buildings Administration, a series of acceptance tests was made on an electrostatic precipitator for removing fly ash from the products of combustion at the West Central Heating Plant, Washington, D. C.; the equipment finally met contract requirements after needed changes. Cost comparisons when different fuels were used were determined for two hospitals of the Veterans Administration. At the request of the Federal Supply Service, tests were made of operating characteristics of a large number of coals delivered for trial at various plants in the Washington, D. C., area; the results of these tests were used in determining

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

awards for contracts for large tonnages of coal. At the request of the Department of Justice, estimates were made of annual overall operating costs when different fuels are used in a proposed new power plant at Atlanta, Ga., choice of fuel, design of boiler plant, and type of fuel-burning equipment were determined. At the request of the State government of Virginia and the Virginia Polytechnic Institute, fuel-burning difficulties at the institute were studied and recommendations made to improve conditions.

The results of several years research on the substitution in domestic-heating equipment of the less costly Pea-size anthracite for the normally used larger sizes were given at the Tenth Annual Anthracite Conference of Lehigh University. 66/ It was found that, under regular operating and good firing conditions, an average of 89.2 percent of the heat of the Pea anthracite went into the water of a cast-iron heating boiler. Under these conditions, unburned combustible in the refuse ranged from 1.8 to 4.0 percent, and the pounds of refuse per pound of coal ranged from 8 to 10 percent. For the same furnace somewhat more draft is required when burning pea size to produce the same general results. Although Pea anthracite, on the average, may contain a few percent fewer heat units and somewhat more ash by analyses, as a practical matter, evidence of these differences often disappears in the handling of the furnace or in variations of firing methods. Since it sells from about $3.00 up to $4.50 less per ton that the usually more-favored larger sizes, it is a more economical fuel when it can be used. Success in its use depends to a greater extent upon the fireman than upon the equipment.

As part of a project sponsored by the American Society for Testing Materials, a Bureau of Mines publication was compiled containing operating experience as to the significance of ASTM laboratory tests of coal and coke for combustion. 67/ A number of highly experienced fuel engineers throughout the United States aided in preparing this publication, which covers the use of bituminous coal, anthracite, and coke in many types of fuel-burning equipment. The laboratory tests considered included proximate and ultimate analyses, calorific value, fusibility and analysis of ash, fineness and screen analysis, grindability, drop-shatter and tumbler tests, weight per cubic foot, dustiness, free-swelling index, and agglutinating value. Classification of coal by rank and by variety also was considered.

Utilization of Fly Ash

With continually increased firing of pulverized coal, profitable disposal of the fly ash is becoming a problem of greater importance to many utility and industrial companies. Also, in recent years, the public demand for cleaner air and the more highly efficient fly-ash collectors available have resulted in collection of a greater percentage of the fly ash produced. The solution to better utilization of fly ash, therefore, has been the object of research for some years. 68/

Fly ash has been used in some instances with good results as a replacement for an appreciable percentage of the portland cement in concrete mixes. Fly ash also has been used as a portion of the fine aggregates in concrete and as an addition to standard concrete mixes. Other commercial uses are in the manufacture of brick

66/ Barkley, J. F., Domestic Hand Firing of Pea Anthracite: Trans. 10th Ann. Anthracite Conf., Lehigh University, May 8-9, 1952, pp. 106-119.
67/ Barkley, J. F., Significance of Laboratory Tests of Coal and Coke for Combustion: Bureau of Mines Inf. Circ. 7619, 1951, 46 pp.
68/ Morgan, R. E., Utilization of Fly Ash: Bureau of Mines Inf. Circ. 7635, 1952, 30 pp.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

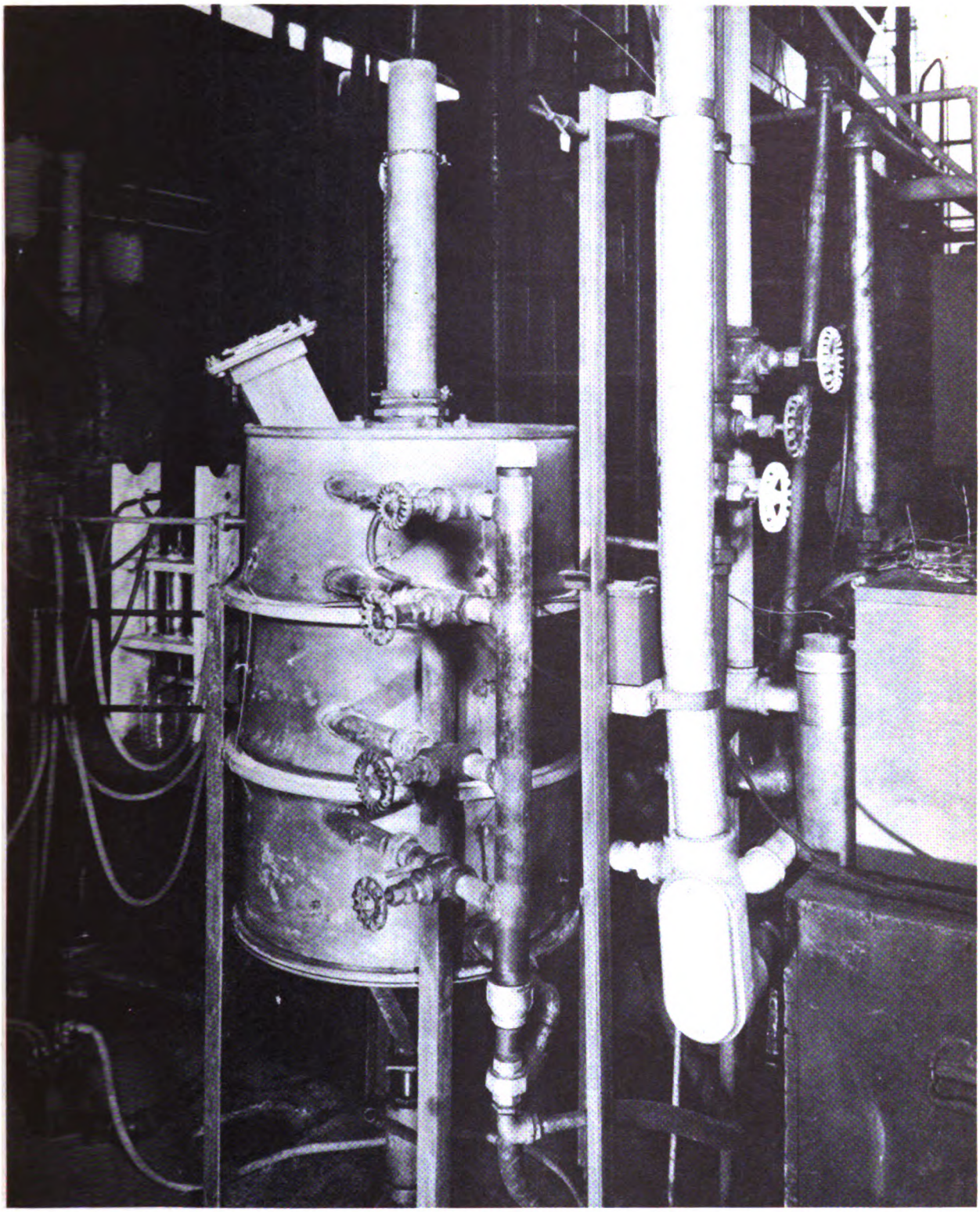

Figure 10. - Model incinerator used to study method for disposal of radioactive wastes. Tangential ports are shown in foreground. Gas-sampling tubes are on left side.

Generated on 2024-09-20 11:08 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:08 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

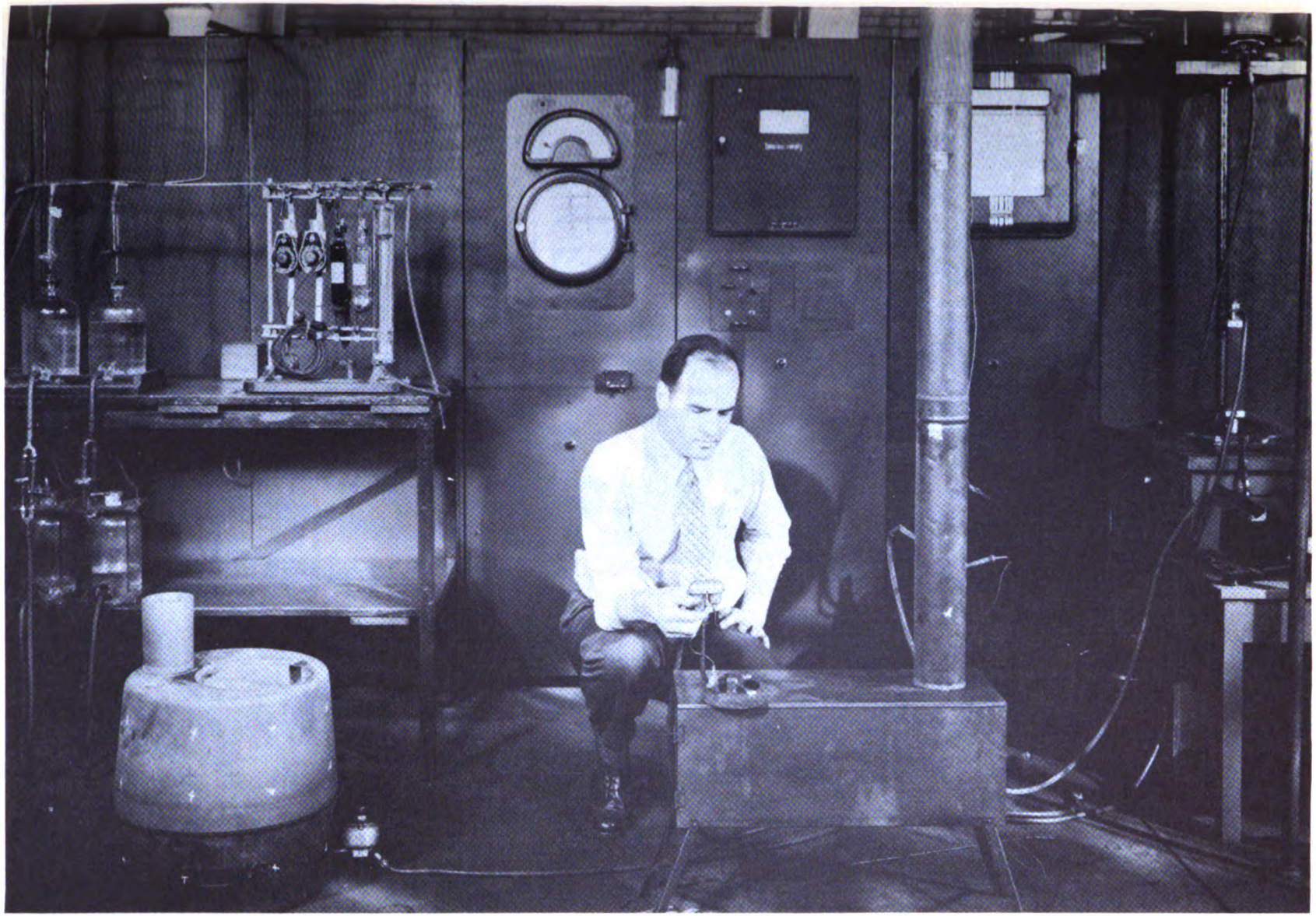

Figure 11. - Portable tent heaters being tested for the Office of Quartermaster General. The M-1941 Stove is shown on the left and the Yukon Stove on the right.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

Digitized by Google

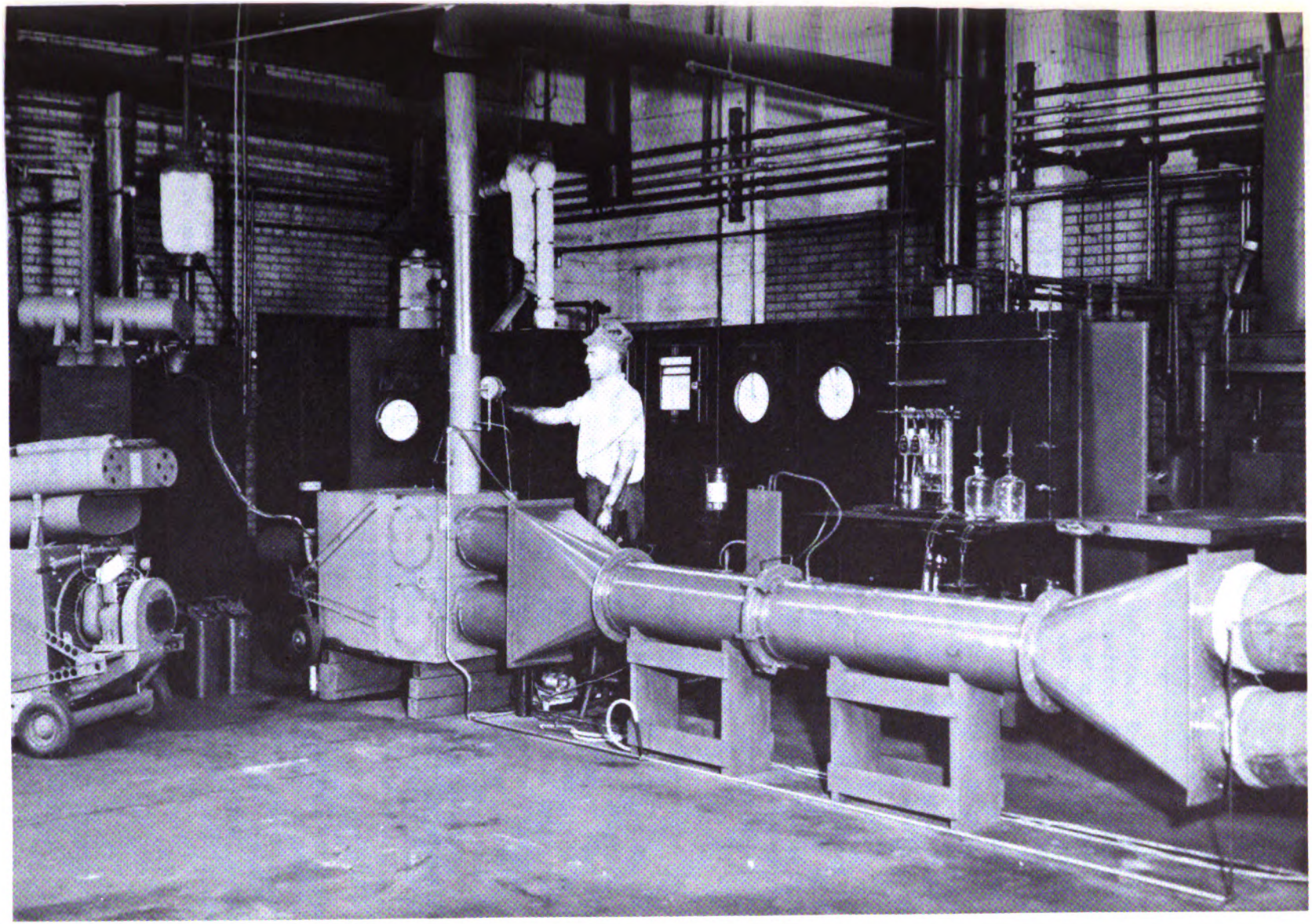

Figure 12. - The Herman-Nelson heater under test. The special duct and orifice for measuring air-flow rate are shown in foreground. In background are test instruments and apparatus.

Original from THE OHIO STATE UNIVERSITY

and in bituminous paving, where the material is used as a mineral filler. Other possible uses that have been tried are: (1) Sand blasting; (2) ingredient for foundry cores in some nonferrous foundries; (3) filler for other materials, such as fertilizer, paint, and putty; and (4) substitute for pumice in mechanics' soap. None of the uses has, as yet, provided a market for over a small percentage of the fly ash collected annually at boiler plants.

Disposal of Radioactive Wastes by Incineration

Continuation of the cooperative project with the Atomic Energy Commission was directed toward the design and development of an incinerator for disposing of radioactive wastes in locations not connected directly with atomic energy sites. The method of collecting the ash residue in a solid flux was completed; the present work is concerned with studies of the combustion process in a model incinerator.

Tests are being conducted to determine the effect of the geometry of the incinerator and the velocity of the combustion air upon the fluid-flow patterns inside the combustion chamber. Also, a correlation is being sought between the flow patterns and the performance of the incinerator. Figure 10 is a view of the model being used in the studies. The most important feature is the use of tangential ports to provide a vortex motion.

Although the specific objective of the program is to develop a process for complete destruction of radioactive materials with a minimum discharge of radioactive particulate matter to the atmosphere, there is also widespread interest in the incineration of all types of waste materials.69/ This interest arises from the almost universal consciousness of the effects of air pollution and from the increasing adoption of ordinances prohibiting such pollution.

Tests of Army Stoves and Cookers

A cooperative investigation is in progress to evaluate the performance of heating equipment for the Office of the Quartermaster General. The objectives of the investigation are to evaluate the thermal efficiency, smoking tendency, dependability, convenience, and safety in use, particularly under adverse conditions of extremely low temperatures or high altitudes. Up to the present time tests have been conducted on the following representative units: (a) 2 portable tent heaters, the Yukon stove and the M-1941 stove, which are designed for burning coal, wood, gasoline, or oil (fig. 11); (b) the Herman-Nelson heater, a gasoline-fired space heater of 250,000-B.t.u.-per-hour capacity, provided with a gasoline-engine-driven forced-circulation fan (fig. 12); (c) the Hayter 5-pound stove, a compact emergency heater burning gasoline and intended primarily to be dropped from aircraft in isolated locations; and (d) immersion heaters, oil- or gasoline-burning heaters with a toroid-shaped combustion chamber used to heat liquids.

A number of improvements were recommended to increase the thermal efficiency, to reduce smoke, and to increase the safety and convenience features of several of the heaters. One type of burner was found to be hazardous at very low temperatures, although it could be used safely under normal conditions. Since this situation arises from the vapor-pressure characteristics and the explosibility limits inherent in the fuel, the burner could not be made safe under the most adverse conditions. Accordingly, its use in tent-heating equipment was discontinued.

69/ Corey, R. C., Some Fundamental Considerations in the Design and Use of Incinerators in Controlling Atmospheric Pollution: Air Pollution, McGraw-Hill Book Co., New York, 1952, pp. 394-407.

Generated on 2024-09-20 11:06 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

OTHER INVESTIGATIONS RELATED TO FUEL UTILIZATION

Boiler-Feed-Water Conditioning

Analyses and resulting recommendations were made on 11,240 samples of boiler water, an increase of about 16 percent over the previous year. Nearly 70 percent of the samples were from the Department of National Defense, 16 percent from the Veterans Administration, and the remainder from other agencies of the Government.

Reports and recommendations were made covering 17 analyses of various boiler-plant scales and deposits; 14 miscellaneous special water analyses, including analyses for silica for controlling boiler-water treatment with sodium silicate and for contaminations such as soap for control of boiler foaming; and 2 analyses of boiler compounds.

A total of 1,112 special Bureau of Mines field water-test kits, 14,961 bottles of chemical reagents, and 19,464 test-kit replacement items were distributed to various Government activities. This is about a 24-percent increase over the previous year. Distributing these kits and reagents from a central source saved Government agencies about $25,000 this year, as compared to open market purchase.

Visits were made to a number of heating plants operated by various Federal agencies in the local area of the District of Columbia to investigate difficulties, advise on boiler-water treatment, give instructions in boiler-water testing, inspect boilers for scale and sludge, and improve efficiency of operation. At the request of the Baltimore Housing Authority, Baltimore, Md., a visit was made to its boiler plants to make recommendations as to improved operation, and the U. S. Detention Headquarters, Danbury, Conn., was visited, and recommendations were made. At a request from the Government Printing Office, Washington, D. C., studies were made of corrosion occurring in brass hot-water lines, and means were determined for abatement.

Consulting services were given the Department of the Army on zeolite softeners, testing methods for control of amine concentration in condensates, control of amine bicarbonate deposits in steam lines in the Second Army area, acid cleaning boilers, boiler-water testing and use of test kits, and measuring conductivity of boiler water for control of rate of blowdown; to the Department of the Air Force and its commands on control of return-line corrosion, choice of boiler-water treatment for reducing carbon dioxide concentration in condensates, testing boiler water for dissolved solids, control of scale formation in distillation units, use of various electric equipment for boiler-water treatment, external treatment of boiler feed water, control of return-line corrosion, chemical feeding equipment, and protection of hot-water heaters from corrosion; to the Department of the Navy and its districts on protection of hot-water circulating systems from corrosion, use of commercial boiler-water compounds, protection of hot-water heaters from corrosion, calculating CO_2 concentration in steam from raw-water analyses, control of boiler-water contamination causing carryover, acid cleaning of hot-water heaters, control of return-line corrosion, the conductivity test of boiler water, use of chromates, phosphates, and silicates for treating cooling water, boiler-water sampling coils, the colorimetric hardness test for boiler water including furnishing two special test kits for the test, and the use of caustic soda for boiler-water treatment; to the Veterans Administration and its stations on control of boiler corrosion and control of boiler-scale formation; to the District of Columbia Government, Bureau of Reclamation, Yellowstone National Park, Wyo., and the Department of Justice on boiler-water treatment.

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The total number of boilers being serviced increased to a little more than 8,000. On the basis of savings reported by representative plants and assuming similar savings in all the plants, a total savings well above $20,000,000 per year is being achieved by Government agencies through the Bureau of Mines boiler-water-conditioning program.

Boiler Water Research

Research work was continued on the use of chemicals to prevent corrosion in condensate piping in Government heating systems. Relatively rapid corrosion of such piping may occur in systems covering large areas when the condensated steam is even normally acidic. Chemical treatment neutralizes the acidity and thus removes the principal cause of the corrosion. Representative plants have used an amine to protect condensate piping at a cost of less than $1 per million pounds of steam produced. A special test nipple containing weighed tubular inserts was developed to measure corrosion rates in the field tests. The device is installed as part of the condensate piping, and the inserts are examined carefully either monthly or annually, depending on whether the chemical treatment is being given a short test or a long one. The results need no extrapolation, since they are obtained with "pipe" of the same size and similar composition as the condensate piping. Similar testing devices have been used to furnish practical data on the tendency for the amines to cause corrosion of brasses under various conditions.

A survey[70] was made of the use that industry is making of the Bureau of Mines embrittlement detector in connection with the problem of boiler-seam cracking. The Bureau of Mines embrittlement-detector test not only will show if an unsafe condition exists, but the effect of treatments to prevent cracking can be evaluated in terms of test-specimen resistance to failure. Three practical methods of treatment were developed by the Bureau. Sodium nitrate and organic substances, such as tannin and lignin, were shown to inhibit the intercrystalline corrosion of steel in hot solutions of caustic soda or caustic potash. Also effective was elimination of free sodium hydroxide from the boiler water by maintaining only the alkalinity corresponding to trisodium phosphate. The principal conclusion from case histories of boilers cracked in the last 10 years is that, with the present available treatments, preventing embrittlement cracking is no longer a serious problem.

Utilization of residual fuel oils in power boilers has, in some instances, resulted in a special type of corrosion. The trouble appears most likely to occur where combustion conditions and design cause the ash from high-vanadium oils to pass over metal surfaces at comparatively high temperature. The ash content of fuel oil is generally less than 0.1 percent, and only a small portion of the ash is deposited on a probe placed in the hot-gas stream. A laboratory study of the problem therefore required a method for determining vanadium in very small samples. A phosphotungstic acid method was successfully adapted for this purpose.[71] A 20-milligram sample of the ash is dissolved in nitric and sulfuric acids and a yellow phospho-vanadium-tungstate complex is developed by adding phosphoric acid and sodium tungstate. The color is compared to standards, and as little as 0.005 milligram of vanadium can be detected.

70/ Berk, A. A., The Prevention of Embrittlement Cracking: Trans. Am. Soc. Mech. Eng., vol. 73, 1951, pp. 859-864.

71/ Hopps, G. L., and Berk, A. A , Determination of Vanadium in Fuel-Oil Ash: Anal. Chem., vol. 24, 1952, pp. 1050-1051.

Generated on 2024-09-20 11:09 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Mine-Refuse Fires

Increasing awareness of the public of the harmful effects of air pollution is prompting concerted action by public and private groups to abate or eliminate all sources of such pollution. In the concentrated coal-producing areas, such as Pennsylvania, Ohio, and West Virginia, are thousands of piles of unsalable refuse from coal mines and coal washeries that are prone to ignite spontaneously and produce smoke and fumes that create a serious nuisance to nearby communities.72/ Many of these piles, popularly known as gob piles, have burned for many years, and token efforts to extinguish some of them have been unsuccessful, largely because of the expense and because the fundamental factors involved in spontaneous ignition are not clearly understood.

Recent legislation in some of the affected areas, (for example, Allegheny County, Pa.), has provided the mine owners a definite time in which to devise means for preventing gob pile fires, and for extinguishing existing fires. But until the fundamental causes of such fires are better understood, permanently effective control measures cannot be devised. In this connection the Bureau of Mines initiated an investigation regarding the fundamental causes and the engineering solution of gob-pile fires. In the first phase, laboratory and field experiments were begun to ascertain the effects of the geometry of gob piles and of the composition and physical characteristics of the coal refuse comprising gob piles. Other phases of the problem that will be included as the investigation proceeds are shown in figure 13.

Smoke Abatement

Smoke-abatement work throughout the United States continued quite active. Cities requesting Bureau of Mines publications and consulting service included the following: Groton, Conn.; Des Moines, Iowa; Hinsdale and Joliet, Ill.; Herkimer and New York, N. Y.; and Ocala, Fla. At the request of the National Research Council, the Bureau participated with other institutions in developing standardized units of measurement for air contaminants. Work on air-pollution difficulties at the international boundary line between Canada and the United States, in the vicinity of the Detroit River, was continued for the International Joint Commission by its Technical Advisory Board on Air Pollution, which includes a Bureau of Mines engineer as one of its three United States members. Comprehensive studies of the amount of air pollution and its effects were made; smoke from river vessels was reduced somewhat, and plans were continued for obtaining further improvement.

Stream Pollution

Samples of water from mines in the anthracite region were collected, and analyzed and the results reported. Factual data regarding water impounded in underground pools and in abandoned strippings were obtained that constitute an important part of information being gathered by the Bureau of Mines pertinent to the collection and ultimate disposal of mine drainage in the anthracite region. Recent studies and reports on pumping and field work concerning drainage tunnels extended materially the information available on the mine-water problem and emphasized the importance of presenting salient factors concerning acid mine drainage in the region.73/

72/ Brewer, R. E., Discussion of paper by R. E. Zimmerman, The Atmospheric Pollution Problem of Mine Refuse Piles: Air Pollution, McGraw-Hill Book Co., Inc., New York, 1952, pp. 80-83. Pres. at U. S. Tech. Conf. on Air Pollution, Interdepartmental Committee on Air Pollution, May 3-5, 1950.

73/ Ash, S. H., Felegy, E. W., Kennedy, D. O., and Miller, P. S , Acid-Mine-Drainage Problems, Anthracite Region of Pennsylvania: Bureau of Mines Bull. 508, 1951, 72 pp.

Generated on 2024-09-20 11:07 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:09 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

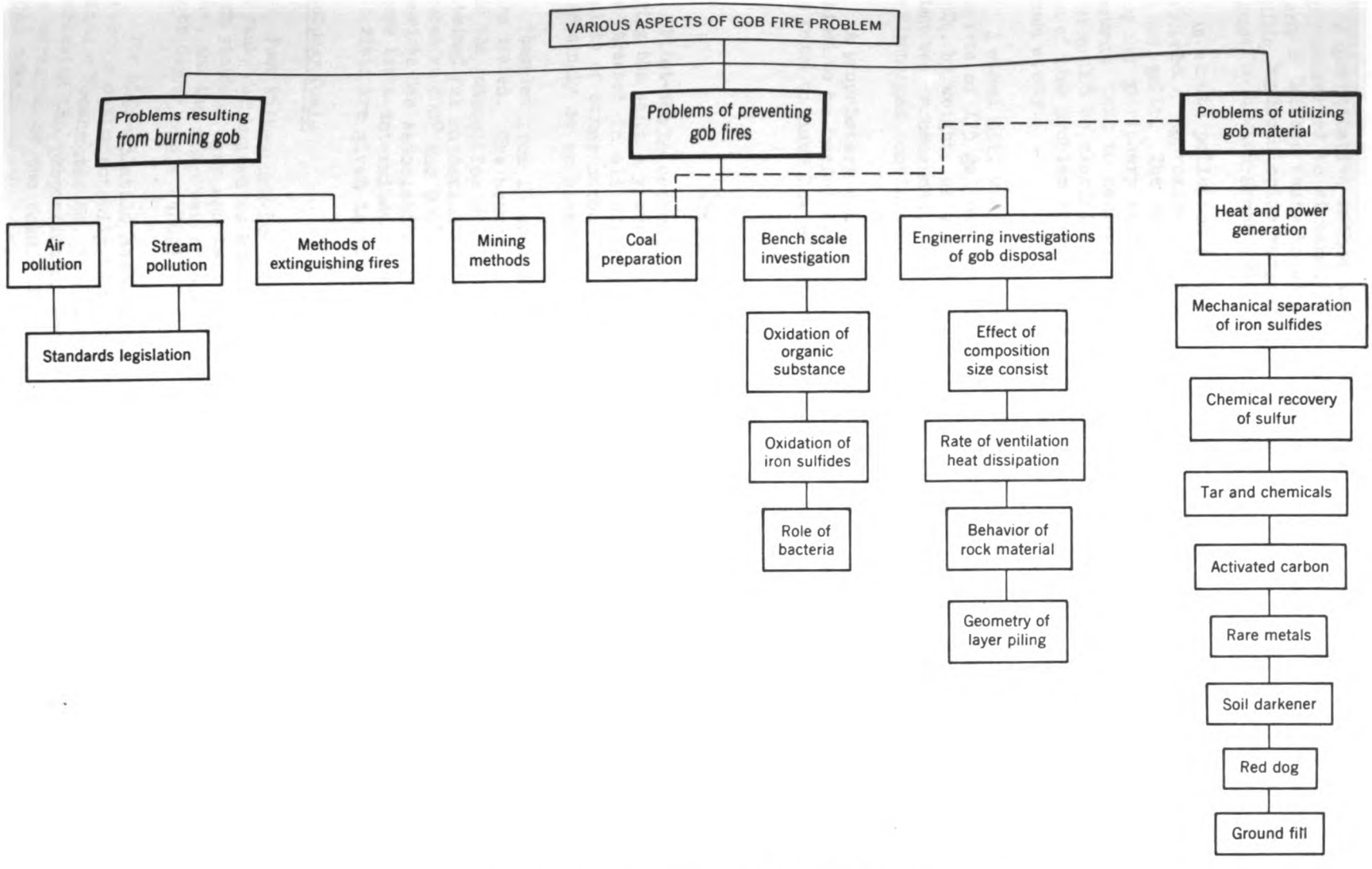

Figure 13. - Aspects to be considered in gob-pile investigation.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

A quantitative method was developed for analyzing pine oil in flotation tailings discharged to streams. Pine oil in concentrations even as low as 10 p.p.m. imparts a bitter taste to water. A colorimetric method was devised by which a vanillin hydrochloride reagent, when added to a water sample containing pine oil, produces a bluish-green color.

An acute pollution problem caused by acid drainage from a coal-storage pile was solved. Approximately 1 ton of sulfuric acid per week drained from the 15,000-ton coal pile. The recommended solution of the problem was to install a gutter along the periphery of the coal pile to collect the drainage from the pile, a treatment tank to neutralize this drainage, and a catch basin in which the treated water would be clarified before it found its channel to the watershed. This solution of the problem cost about $200,000 less than solutions proposed before the Bureau study.

A steel mill was discharging alternate batches of caustic solutions at a maximum rate of 175 gallons per minute, and spent pickling wastes as high as 15 percent H_2SO_4, by weight, at a maximum rate of 225 gallons per minute. A neutralization plant was recommended, so that a relatively small quantity of neutral waste would be discharged continuously to the local stream.

A proprietary substance, found to be essentially dolomitic limestone and claimed to be useful for treating municipal sewage containing industrial wastes, was found to have low effectiveness in the neutralization of acid mine waters.

CARBONIZATION OF COAL

Survey of Carbonizing Properties of American Coals

Pilot-scale carbonization tests at high temperatures only were continued, as during the past 4 years. The suitability of coals for making metallurgical coke was stressed in all experimental carbonization tests, although the yields and quality of other carbonization products were determined. Most coals were carbonized singly or as blends to evaluate their carbonizing properties more completely.

Samples from 15 coal beds in the Appalachian region and from 4 beds in Utah were tested. The source, proximate analysis, and sulfur content of the coals used and the composition of the blends are given in table 1, which also includes samples obtained for oxidation and expansion tests. Most Appalachian region coals were tested at 800° and 900° C. in the standard 18-inch retort by the Bureau of Mines-American Gas Association (BM-AGA) methods. Physical properties of the cokes from these tests determined by standard methods of the American Society for Testing Materials are given in table 2 by States and summarized below.

Kentucky Coals

Four Whitesburg-bed coals (488, 489, 490, and 491), high-volatile A bituminous in rank, carbonized as blends at 900° C. gave relatively low yields of coke and high yields of gas and tar. The blend of Letcher County coals (488A) yielded more coke, and the coke was stronger, although more abradable, than that of the blend of Knott County coals (489A).

The high-volatile Mason-bed coal (495) yielded coke with a low stability factor and a satisfactorily high hardness factor. Blending with 20 percent of low-volatile Pocahontas No. 3 coal raised the shatter and 1-inch tumbler indexes. Increasing the proportion of Pocahontas No. 3 coal to 30 percent generally increased the strength of the coke. Either blend would be suitable for producing metallurgical coke.

Generated on 2024-09-20 11:08 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

TABLE 1. - Description and analyses of coals and proportions used in blends

Coal No.	Description	Analysis, percent					
		Proximate					Dry, mineral-matter-free fixed carbon
		Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
	Alabama						
500	Pratt bed, Docena mine, Jefferson County	2.4	29.0	62.6	6.0	1.7	68.9
500A	Blend: 50 percent Pratt (500) and 50 percent Pratt (501)	-	-	-	-	-	-
501	Pratt bed, Edgewater mine, Jefferson County	2.7	24.7	65.9	6.7	1.5	73.4
502	America bed, Concord mine, Jefferson County	3.5	25.1	65.7	5.7	.9	72.9
522	Blend: 24 percent Pratt bed, Docena mine; 8 percent Pratt bed, Edgewater mine; 16 percent Mary Lee bed, Hamilton mine; 34 percent Pratt bed, Short Creek mine; and 18 percent America bed, Concord mine	2.2	27.9	62.4	7.5	1.4	69.8
	Kentucky						
488	Whitesburg bed, Prospect No. 3 opening, Letcher County	3.5	36.5	53.5	6.5	.7	59.9
488A	Blend: 50 percent Whitesburg (488) and 50 percent Whitesburg (490)	-	-	-	-	-	-
489	Whitesburg bed, Prospect in Floyd Campbell mine, Knott County	3.0	40.5	53.7	2.8	.7	57.2
489A	Blend: 50 percent Whitesburg (489) and 50 percent Whitesburg (491)	-	-	-	-	-	-
490	Whitesburg bed, Prospect mine, Letcher County	2.9	36.2	53.5	7.4	.8	60.2
491	Whitesburg bed, Prospect mine, Knott County	3.1	38.5	54.0	4.4	1.1	58.7
495	Mason bed, Bell Ridge mine, Bell County	3.1	37.3	57.1	2.5	.8	60.7
495A	Blend: 80 percent Mason (495) and 20 percent Pocahontas No. 3 (175)	-	-	-	-	-	-
495B	Blend: 70 percent Mason (495) and 30 percent Pocahontas No. 3 (175)	-	-	-	-	-	-
524	Bell (1B) bed, Bell No. 1 mine, Crittenden County	6.2	32.1	54.8	6.9	1.5	63.7
	Pennsylvania						
499	Lower Freeport bed, Kramer mine, Jefferson County	1.9	29.6	60.0	8.5	1.3	67.7
499A	Blend: 80 percent Lower Freeport (499) and 20 percent Pocahontas No. 3 bed (J75)	-	-	-	-	-	-
499B	Blend: 70 percent Lower Freeport (499) and 30 percent Pocahontas No. 3 bed (J75)	-	-	-	-	-	-
513	Upper Freeport bed, Kent No. 2 mine, Indiana County	1.1	32.3	59.2	7.4	1.8	65.4
514	Upper Freeport bed, Kent No. 8 mine, Indiana County	1.2	28.6	62.0	8.2	1.2	69.2
515	Upper Freeport bed, Kent No. 3 mine, Indiana County, strip coal	1.2	28.3	62.6	7.9	1.0	69.5
516	Lower Freeport bed, Kent No. 1 mine, Indiana County	.8	29.3	61.5	8.4	1.1	68.4
517	Blend: 33 percent Upper Freeport (513), 18 percent Upper Freeport (514), 31 percent Upper Freeport (515), and 18 percent Lower Freeport (516)	1.2	29.6	61.0	8.2	1.2	68.0
	Utah						
504	Rock Canyon bed, Carbon County, core-drill sample	2.2	38.8	52.6	6.4	.8	58.0
505	Gilson bed, Carbon County, core-drill sample	2.0	38.2	49.9	9.9	.6	57.3
506	Upper Sunnyside bed, Carbon County, core-drill sample	1.9	35.8	44.2	18.1	.7	56.6
507	do.	2.0	36.6	44.3	17.1	1.0	56.0
508	Lower Sunnyside bed, Carbon County, core-drill sample	2.2	37.2	50.0	10.6	.7	58.1
	Virginia						
483	Clintwood bed, Moss mines 1, 2, and 3, Dickenson County, and Meade mine, Wise County	2.0	31.8	62.2	4.0	.8	66.5
483A	Blend: 80 percent Clintwood (483) and 20 percent Pocahontas No. 3 (h75)	-	-	-	-	-	-
483B	Blend: 70 percent Clintwood (483) and 30 percent Pocahontas No. 3 (175)	-	-	-	-	-	-
484	Tiller bed, No. 201 mine, Russell County	2.1	31.9	59.6	6.4	.5	65.6
484A	Blend: 80 percent Tiller (484) and 20 percent Pocahontas No. 3 (175)	-	-	-	-	-	-
484B	Blend: 70 percent Tiller (484) and 30 percent Pocahontas No. 3 (175)	-	-	-	-	-	-
485	Jawbone bed, Rasick mine, Russell County	1.8	31.4	54.6	12.2	.7	64.5
485A	Blend: 80 percent Jawbone (485) and 20 percent Pocahontas No. 3 (175)	-	-	-	-	-	-
485B	Blend: 70 percent Jawbone (485) and 30 percent Pocahontas No. 3 (175)	-	-	-	-	-	-
486	Splashdam bed, Splash Dam mine, Dickenson County	1.8	29.5	62.4	6.3	.8	68.4
486A	Blend: 80 percent Splashdam (486) and 20 percent Pocahontas No. 3 (h75)	-	-	-	-	-	-
486B	Blend: 70 percent Splashdam (486) and 30 percent Pocahontas No. 3 (175)	-	-	-	-	-	-
509	Taggart bed, Dixiana mine, Wise County	1.9	33.9	61.6	2.6	.7	64.7
509A	Blend: 80 percent Taggart (509) and 20 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
509B	Blend: 70 percent Taggart (509) and 30 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
510	Upper Banner bed, Toms Creek mine, Dickenson County	1.6	34.8	56.1	7.5	.7	62.3
510A	Blend: 80 percent Upper Banner (510) and 20 percent Pocahontas No. 3 (J75 in expansion and K75 in BM-AGA tests)	-	-	-	-	-	-
510B	Blend: 70 percent Upper Banner (510) and 30 percent Pocahontas No. 3 (J75 in expansion and K75 in BM-AGA tests)	-	-	-	-	-	-
511	Norton bed, Dorchester mine, Wise County	1.9	33.0	58.5	6.6	1.1	64.5
511A	Blend: 80 percent Norton (511) and 20 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
511C	Blend: 95 percent Norton (511) and 5 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
a511	Norton bed, Dorchester mine, Wise County (slack coal used for coke manufacture)	-	-	-	-	-	-
a511A	Blend: 90 percent Norton (a511) and 10 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
a511B	Blend: 85 percent Norton (a511) and 15 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
a511D	Blend: 80 percent Norton (a511) and 20 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
	West Virginia						
413	Upper Freeport bed, Bull Run No. 1 mine, Preston County	2.8	27.7	60.9	8.6	1.0	69.7
503	Pittsburgh bed, Gilmer County (composite from 7 mines)	2.6	39.6	48.2	9.6	2.4	55.5
503A	Blend: 80 percent Pittsburgh (503) and 20 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
503B	Blend: 70 percent Pittsburgh (503) and 30 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
523	Sewell bed, Brooklyn mine, Fayette County	2.9	23.4	66.0	7.7	.7	74.5
525	Upper Kittanning bed, LeMoyne No. 2 mine, Clay County	2.5	39.9	50.7	6.9	1.7	56.5
525A	Blend: 80 percent Upper Kittanning (525) and 20 percent Pocahontas No. 3 (k75)	-	-	-	-	-	-
525B	Blend: 70 percent Upper Kittanning (525) and 30 percent Pocahontas No. 3 (k75)	-	-	-	-	-	-
525C	Blend: 95 percent Upper Kittanning (525) and 5 percent Pocahontas No. 3 (k75)	-	-	-	-	-	-
	Miscellaneous						
493	Pittsburgh (No. 8 bed), Georgetown mine, Harrison County, Ohio	4.9	38.5	49.6	7.0	2.5	56.9
494	Pittsburgh (No. 8 bed), Piney Fork No. 1 mine, Jefferson County, Ohio	4.1	38.0	50.4	7.5	2.7	57.7
496	No. 4 bed, La Chapa mine, Colombia, South America	2.6	36.6	55.3	5.5	.8	60.6
497	No. 3 bed, La Chapa mine, Colombia, South America	2.1	34.9	50.1	12.9	2.1	60.0
	Blending coals						
p28	Pittsburgh bed, Warden mine, Allegheny County, Pa	2.1	35.5	56.9	5.5	.9	62.0
s28	do.	1.8	35.4	57.7	5.1	.9	62.4
t28	do.	1.7	34.6	57.7	6.0	.9	63.0
s28A	Blend: 80 percent Pittsburgh (s28) and 20 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
s28B	Blend: 70 percent Pittsburgh (s28) and 30 percent Pocahontas No. 3 (J75)	-	-	-	-	-	-
h75	Pocahontas No. 3 bed, Carswell mine, McDowell County, W. Va	2.7	16.8	74.1	6.4	.6	82.2
175	do.	4.1	16.2	71.3	8.4	.6	82.3
J75	do.	3.6	16.5	72.8	7.1	.7	82.2
k75	do.	2.1	16.7	73.8	7.4	.7	82.3

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

TABLE 2. - Physical properties of coke
(A. S. T. M. Method)

Coal No.	Carbonizing temperature, °C.	True specific gravity	Apparent specific gravity	Cells, percent	Shatter test, cumulative percent upon- 2-inch screen	1-1/2-inch screen	1-inch screen	1/2-inch screen	Tumbler test, cumulative percent upon- 2-inch screen	1-1/2-inch screen	1-inch screen	1/2-inch screen	1/4-inch screen
							Kentucky						
488A	900	1.91	0.83	56.5	50	77	93	96	0	8	37	56	60
489A	900	1.88	.78	58.5	21	46	79	93	0	0	7	43	67
495	800	1.84	.76	58.7	57	71	84	95	0	1	12	44	61
495	900	1.86	.78	58.1	37	67	88	96	0	1	20	57	67
495A	800	1.85	.78	57.8	80	91	96	98	3	27	49	59	60
495A	900	1.88	.80	57.4	44	78	94	97	0	11	45	64	66
495A[1]	900	-	.87	-	38	73	93	98	0	8	42	67	69
495B	800	1.85	.79	57.3	84	94	97	98	9	41	56	60	60
495B	900	1.88	.80	57.4	45	80	94	98	1	11	47	65	67
524	900	1.93	.78	59.6	65	85	94	96	1	11	38	51	54
							Pennsylvania						
499	800	1.90	.91	52.1	76	88	94	97	4	21	42	58	62
499	900	1.92	.91	52.6	59	86	94	97	0	14	47	61	64
499A	800	1.89	.86	54.5	87	94	97	98	17	46	55	59	59
499A	900	1.92	.86	55.2	70	90	96	98	3	29	55	62	63
499B	800	1.88	.85	54.8	91	96	97	98	27	51	58	59	59
499B	900	1.92	.86	55.2	73	92	97	98	6	33	56	62	63
							Virginia						
483	800	1.86	.91	51.1	70	88	94	97	1	17	37	57	61
483	900	1.90	.90	52.6	43	81	95	98	0	10	44	61	63
483A	800	1.87	.88	52.9	85	94	97	98	13	44	58	60	61
483A	900	1.90	.89	53.2	51	85	96	98	1	15	51	64	65
483B	900	1.89	.88	53.4	60	85	95	98	2	18	52	63	65
484	800	1.88	.85	54.8	73	84	91	96	8	15	30	48	53
484	900	1.91	.86	55.0	47	77	92	96	0	6	29	52	57
484A	800	1.87	.86	54.0	85	95	97	98	14	39	54	58	58
484A	900	1.91	.87	54.5	56	85	95	97	1	14	44	60	62
484A[1]	900	-	.90	-	47	79	94	98	1	11	42	62	64
484B	900	1.92	.87	54.7	57	85	96	98	2	16	48	61	63
485	800	1.94	.92	52.6	58	72	84	93	6	17	27	43	51
485	900	1.97	.96	51.3	50	68	83	93	0	10	22	46	56
485A	800	1.93	.91	52.8	62	77	88	94	7	18	33	49	55
485A	900	1.96	.92	53.1	42	67	86	95	3	12	31	53	59
485B	900	1.95	.92	52.8	55	76	90	96	2	11	34	56	62
486	800	1.87	.91	51.3	79	91	96	97	7	30	50	59	61
486	900	1.90	.91	52.1	60	86	96	98	0	17	49	61	64
486A	800	1.87	.88	52.9	89	95	97	98	22	48	58	61	62
486A	900	1.91	.89	53.4	61	88	96	98	2	24	55	65	67
486B	900	1.91	.86	55.0	65	88	96	98	5	25	53	62	64
509	800	1.82	.81	55.5	73	84	92	97	2	15	31	52	58
509	900	1.86	.84	54.8	49	82	94	97	0	6	41	61	64
509A	800	1.84	.82	55.4	86	94	97	98	12	41	55	59	59
509A	900	1.87	.82	56.1	55	87	96	98	1	17	52	64	65
509B	800	1.83	.80	56.3	90	95	97	98	22	48	57	58	59
509B	900	1.86	.81	56.5	59	87	96	98	3	20	52	63	64
510	800	1.88	.94	50.0	72	83	89	95	0	5	17	45	57
510	900	1.91	.96	49.7	62	80	91	95	0	2	23	49	58
510A	800	1.88	.90	52.1	84	92	95	97	6	27	46	56	57
510A	900	1.91	.94	50.8	59	83	94	97	0	7	37	59	63
510B	800	1.88	.90	52.1	88	94	96	97	10	36	51	57	58
510B	900	1.93	.93	51.8	64	85	94	97	1	10	41	60	63
511	800	1.87	.82	56.1	78	87	94	97	4	20	34	52	57
511	900	1.89	.83	56.1	59	87	95	97	0	13	45	58	61
511A	800	1.89	.82	56.6	64	90	96	98	1	21	51	61	62
511A	900	1.91	.89	53.4	50	73	85	93	0	2	20	43	55
511B	900	1.91	.87	54.5	61	83	92	96	0	6	32	49	54
		1.93	.88	54.4	62	86	94	97	0	8	34	52	56
							West Virginia						
503	800	1.90	.81	57.4	56	67	78	92	0	1	6	33	52
503	900	1.95	.87	55.4	55	72	82	92	0	2	13	33	50
503A	800	1.89	.81	57.1	85	90	94	97	7	25	40	49	51
503A	900	1.95	.82	57.9	71	88	94	97	2	19	41	54	57
503B	800	1.90	.82	56.8	91	95	96	97	16	40	49	53	53
503B	900	1.96	.81	58.7	69	89	95	97	2	17	45	58	59
523	900	1.92	.86	55.2	68	87	96	97	1	24	49	58	60
525	800	1.88	.79	58.0	57	70	83	95	0	3	17	49	62
525	900	1.92	.82	57.3	40	70	87	95	0	2	21	53	65
525A	800	1.88	.80	57.4	79	89	94	97	8	27	44	56	58
525A	900	1.94	.82	57.7	50	82	94	97	1	12	45	62	65
525B	800	1.89	.82	56.6	84	93	96	97	10	38	54	59	60
525B	900	1.93	.81	58.0	54	82	94	97	0	12	46	63	65
							Standard blending coals (for comparison only)						
p28	900												
s28A	900	1.86	.83	55.4	38	81	95	97	0	9	47	62	64
s28B	900	1.89	.84	55.6	48	86	96	98	1	16	53	65	67
		1.90	.84	55.8	55	87	97	98	2	20	54	64	66

1/ High charge density.

5471

Generated on 2024-09-20 11:09 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The Bell-bed coal (524) of high-volatile A bituminous rank yielded coke that was rather abradable. Probably this coal could be used to produce blast-furnace coke if blended with suitable coal of higher rank.

In addition to the coals listed in table 1, carbonization tests were reported on four eastern Kentucky coals from the Elkhorn No. 1, Elkhorn No. 2, Leatherwood, and Harlan beds.[74] The cokes from the single coals were well fused but extensively fissured. Their shatter and tumbler indexes were low, particularly the tumbler. Blends with 20 percent of Pocahontas No. 3 coal coked much more strongly than the single coals. Generally, the physical properties of the cokes were improved slightly by increasing the proportion of Pocahontas No. 3 coal to 30 percent. The blends of Elkhorn No. 3, Leatherwood, and Harlan coals with Pocahontas No. 3 coal should be carbonized at moderate charge density as they may expand enough at high densities to damage oven walls.

Pennsylvania Coals

Lower Freeport coal (499) of high-volatile A bituminous rank coked strongly when carbonized singly, and the coke was of large size. Blending with 20 percent of Pocahontas No. 3 coal increased the shatter and tumbler indexes significantly, with the exception of the 1/4-inch tumbler index. These indexes were not changed appreciably by raising the proportion of Pocahontas No. 3 coal in the blend to 30 percent.

Virginia Coals

Carbonization tests were made of seven coals of high-volatile A bituminous rank.

Clintwood-bed coal (483) and Splash Dam-bed coal (486) coked strongly. The hardness and stability of the coke were improved by blending with 20 percent Pocahontas No. 3 coal; no additional improvement resulted from increasing the proportion of Pocahontas No. 3 to 30 percent.

Upper Banner-bed coal (510) coked singly had rather low stability. Blending with Pocahontas No. 3 coal improved the coke markedly; the maximum coke strength was obtained in the blend with 30 percent of Pocahontas No. 3.

Tiller-bed coal (484) yielded coke that resisted breakage but was abradable. Blending with 20 percent of Pocahontas No. 3 coal yielded coke of blast-furnace quality. Increasing the proportion of Pocahontas No. 3 in the blend to 30 percent did not significantly improve the coke strength.

Jawbone-bed coal (485) yielded coke of low stability and high abradability. Blending with 20 percent of Pocahontas No. 3 coal raised the stability and hardness factors but did not alter the shatter indexes. Raising the proportion of low-volatile coal to 30 percent increased the hardness factor. Probably the coking properties of this coal would be improved by cleaning to a lower ash content.

The coke from Taggart-bed coal (509) had strength indexes within, or close to, the acceptable ranges for blast-furnace coke. Blends containing 20 and 30 percent of Pocahontas No. 3 coal were as strong as those from corresponding blends of the BM-AGA standard high-volatile Pittsburgh-bed coal.

74/ Davis, J. D., Reynolds, D. A., Brewer, R. E., Wolfson, D. E., Naugle, B. W., Frederic, W. H., and Birge, G. W., Carbonizing Properties: Eastern Kentucky Coals from Elkhorn No. 1, Elkhorn No. 2, Leatherwood, and Harlan Beds: Bureau of Mines Bull. 511, 1952, 33 pp.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Run-of-mine Norton-bed coal (511) coked strongly. Blending with 20 percent of Pocahontas No. 3 coal raised all strength indexes significantly. The minus-3/4-inch slack (a511) was less strongly coking. Blending with 10 and 15 percent of Pocahontas No. 3 coal improved the coke-making properties of the slack.

West Virginia Coals

Pittsburgh-bed coal (503), high-volatile A bituminous in rank, yielded weaker coke than the standard high-volatile blending coal (p28) from the same bed. Cokes from blends with 20 and 30 percent of Pocahontas No. 3 coal had satisfactory shatter and 1-inch tumbler indexes. The hardness of these cokes probably would be improved if the coal was cleaned to a lower ash content.

Medium-volatile Sewell-bed coal (523) fused well and yielded a coke of blast-furnace grade.

Coke from Upper Kittanning-bed coal (525) from Clay County was rather weak. The blend with 20 percent of Pocahontas No. 3 coal yielded stronger coke.

The carbonizing properties were reported on Chilton-bed coal from the Lorado No. 5 mine, Lorado, Logan County, W. Va.[75] This coal of high-volatile A bituminous rank yielded coke that resists breakage by impact well but is not quite as hard as average coke from coals of similar rank. Blending with 20 percent Pocahontas No. 3 coal strengthened the 900° C. coke appreciably; no further increase in coke strength was obtained by raising the proportion of Pocahontas No. 3 to 30 percent.

The carbonizing properties of two other West Virginia coals, one from the Pittsburgh bed, Marion County, and the other from the Upper Freeport bed, Preston County, were published also.[76] The Pittsburgh coal ranked as high-volatile A bituminous and the Upper Freeport coal as medium volatile. The Pittsburgh-bed coal yielded well-fused, medium-grained coke that was extensively fissured. Blending with 20 percent Pocahontas No. 3 coal improved the physical properties of the coke markedly. The Upper Freeport coke was medium-grained and strong. Blends with 50, 70, and 80 percent Pittsburgh coal yielded weaker coke than that from 100 percent Upper Freeport. The Pittsburgh coal contracted 8.2 percent in the sole-heated oven, and the Upper Freeport coal expanded 11.9 percent.

Alaska, British Columbia, Utah, and Washington Coals

The Upper Sunnyside (506 and 507), Lower Sunnyside (508), Rock Canyon (504), and Gilson (505) coals in Carbon County, Utah, proved to be coking. The cokes were fine- to medium-grained and had a metallic luster. The Upper Sunnyside coal was well fused in the outer part of the retort but was pebbly toward the center; the high percentage of ash may have influenced the coking of this coal. Cokes from the other three beds were similar to Lower Sunnyside coke from coals of the Columbia and Horse Canyon mines.

75/ Davis, J. D., Reynolds, D. A., Wolfson, D. E., Ode, W. H., and Naugle, B. W., Carbonizing Properties: Chilton Coal from Lorado No. 5 Mine, Lorado, Logan County, W. Va.: Bureau of Mines Bull. 500, 1951, 26 pp.

76/ Davis, J. D., Reynolds, D. A., Brewer, R. E., Wolfson, D. E., Naugle, B. W., and Birge, G. W., Carbonizing Properties: West Virginia Coals from the Pittsburgh Bed, Jamison No. 9 Mine, Marion County, and Upper Freeport Bed, Bull Run No. 1 Mine, Preston County: Bureau of Mines Bull. 506, 1952, 31 pp.

5471

Generated on 2024-09-20 11:14 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

In addition, carbonization properties were reported on 18 other coals, which included 2 from Alaska, 12 from British Columbia, 1 from Utah, and 3 from Washington.77/

These coals ranged in rank from high-volatile B bituminous to medium-volatile bituminous. The high-volatile B bituminous coals ranged from the poorly coking No. 3-bed coal, Lower Matanuska Valley, Alaska, to the Lower Sunnyside coal, Emery County, Utah, yielding a rather weak coke.

The British Columbia coals with the most promising chemical compositions and carbonizing properties were blended successfully with Lower Sunnyside coal in the same proportions that Oklahoma low-volatile coals were blended in a commercial plant using the Lower Sunnyside coal. Three percent of pitch was used in the mixture.

Addition of 3 percent of pitch to blends of Oklahoma and Lower Sunnyside coal increased the coke strength significantly.

Wilkeson No. 2 and No. 3 coals from Pierce County, Wash., with 3 percent of pitch, improved Lower Sunnyside coke when blended with 82 percent of Lower Sunnyside coal.

Expansion Properties of Coals During Carbonization

The expansion behavior of coals was determined in the Bureau of Mines sole-heated, constant-pressure, expansion oven. The test results were calculated and reported as percentage of expansion or contraction at a bulk density of 55.0 pounds per cubic foot, a moisture content of 1.0 percent, and a particle size such that 3 percent or less is retained on a 4-mesh sieve.

The expanding properties of the coals and blends tested are given in table 3. Complete descriptions and chemical analyses of the coals are given in table 1.

The Upper Freeport (513), Upper Kittanning (525), Taggart (509), Tiller (484), Clintwood (483), Norton (a511), Pratt (500), Jawbone (485), and Upper Banner (510) coals contracted from 12.0 percent to 27.5 percent. These coals are considered to be safe for oven use, as it is reported that coals used for coking range from 9 percent contraction to 3 percent expansion when tested in a sole-heated oven. However, in normal commercial coking these coals would be blended with low-volatile coal to improve the coke quality. The blends of coal that expanded (500A, 509A, and 509B) would not be recommended for general oven use except at low bulk densities.

The Mason (495), blend of Alabama coals (522), Splashdam (486), Lower Freeport (499), and Norton (511) coals revealed a contraction range from 1.9 to 7.7 percent. Blends of these coals with 20 and 30 percent Pocahontas No. 3 coal were expanding.

The Freeport coals (514, 515, 516, and 517) and the Alabama coals (501 and 502) were expanding. Normally the Freeport coals are contracting as mined. However, these coals were floated on carbon tetrachloride, which reduced the ash and removed disproportionate percentages of petrographic components; also oxidation occurred during the air drying to evaporate the carbon tetrachloride. These processes changed the coals from contracting to expanding.

77/ Davis, J. D., Reynolds, D. A., Brewer, R. E., Naugle, B. W., Wolfson, D. E., Gibson, F. H., and Birge, G. W., Carbonizing Properties: British Columbia, Matanuska Valley (Alaska) and Washington Coals and Blends of Six of them with Lower Sunnyside (Utah) Coals: Bureau of Mines Bull. 510, 1952, 42 pp.

Generated on 2024-09-20 11:12 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

TABLE 3. - Expanding properties of coal in the sole-heated oven

Coal No.	State	Bed	Expansion,[1] percent
t28	Pennsylvania	Pittsburgh	-18.8
i75	West Virginia	Pocahontas No. 3	+17.6
j75	do.	do.	+23.8
k75	do.	do.	+20.6
510	Virginia	Upper Banner	-27.5
510A		Blend	-12.5
510B		do.	- 5.7
485	do.	Jawbone	-17.6
485A		Blend	- 8.3
485B		do.	- 5.0
500	Alabama	Pratt	-17.2
500A		Blend	+ 5.4
a511	Virginia	Norton	-16.7
a511D		Blend	- 7.5
483	do.	Clintwood	-16.0
483A		Blend	- 3.8
483B		do.	- 1.0
484	do.	Tiller	-14.8
484A		Blend	- 4.9
484B		do.	- 1.8
509	do.	Taggart	-13.9
509A		Blend	+ 4.7
509B		do.	+ 7.0
525	West Virginia	Upper Kittanning	-12.3
525C		Blend	- 4.5
513	Pennsylvania	Upper Freeport	-12.0
511	Virginia	Norton	- 7.7
511C		Blend	- 5.2
511A		do.	+ 1.5
499	Pennsylvania	Lower Freeport	- 7.4
499A		Blend	+ 4.4
499B		do.	+ 6.9
486	Virginia	Splash Dam	- 7.3
486A		Blend	+ 2.7
486B		do.	+ 2.0
522	Alabama	do.	- 3.2
495	Kentucky	Mason	- 1.9
495A		Blend	+ 2.8
495B		do.	+ 5.8
516	Pennsylvania	Lower Freeport	+ 9.9
502	Alabama	America	+10.2
501	do.	Pratt	+10.6
517		Blend	+11.4
514	Pennsylvania	Upper Freeport	+14.8
515	do.	do.	+16.5

1/ End-of-test contraction for contracting coals: Maximum expansion for expanding coals.

In a study of the precision of expansion tests on coal, the probable error, standard deviation, and 95-percent range for the distribution of single tests about their average and the distribution of differences between pairs were tabulated for

Generated on 2024-09-20 11:14 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

the sole-heated and vertical-expansion ovens developed by the Bureau of Mines.[78/] Changes in expansion results were correlated with changes in particle size. Estimating equations were developed for predicting the expansion of blends of high-volatile A coals containing 20 and 30 percent of low-volatile Pocahontas No. 3-bed coal and the expansion of a coal from its dry, mineral-matter-free fixed-carbon content and plasticity. The wall pressure was correlated with the internal gas pressure. The correlation coefficients and the standard error of estimate were given for all the correlations.

Spontaneous-heating Tendencies of Bituminous Coal

The self-heating or spontaneous heating tendencies of 1 medium-volatile and 2 high-volatile A coals and the characteristic rates of oxidation of 2 other high-volatile A coals were determined. The five coals (413, 493, 494, 496, and 497) described in table 1 were investigated as a part of cooperative studies to determine their liability to self-heat or fire spontaneously and to deteriorate in coking properties during shipment and storage. All samples were dried in nitrogen at 100° C. before testing.

Table 4 shows the self-heating rates at selected temperatures for medium-volatile, Upper Freeport-bed coal (413) and high-volatile A, Pittsburgh No. 8-bed coals (493 and 494). The Upper Freeport coal had been in storage 2 years before testing; the Pittsburgh No. 8 coals were tested soon after they were received from preparation plants. The self-heating rates for fresh Upper Freeport coal would be expected to be higher. The effect of screening out the minus-35-mesh portion of the Pittsburgh No. 8 coals would be to reduce the self-heating rates, unless this fine material, if present, had been oxidized previously.

TABLE 4. - Self-heating tendencies of coals

Coal No.	Size range	Self-heating rate in oxygen, °F. per hour at-								
		140 (60	158 70	176 80	194 90	212 100	230 110	248 120	266 130	284 °F. 140 °C.)
413.....	Minus-3/16-inch	2.2	5.3	10.7	12.9	13.2	18.3	27.0	36.6	47.8
493.....	1/4-inch by 35-mesh	3.0	5.1	14.8	26.3	39.8	38.2	59.0	70.8	117.0
494.....	1/4-inch by 35-mesh	2.4	3.1	4.8	7.6	19.3	30.7	48.8	77.6	-

High-volatile A No. 3- and No. 4-bed coals (496 and 497) from Colombia, South America, were oxidized in air at 100° C. Their characteristic oxidation rates were 0.258 and 0.246, respectively, as compared with 0.133 for high-volatile A, Pittsburgh-bed, Warden-mine coal (h28) taken as a standard. The characteristic oxidation rate is defined as the percentage of oxygen consumed per day by weight of the dry, mineral-matter-free coal after it had consumed 1 percent of oxygen by weight. The relative rates of oxidation, 1.94, 1.90, and 1.00, indicate that the 2 South American coals oxidize about twice as fast as the Pittsburgh coal, which shows only slow changes in storage. These South American coals would be expected to lose their carbonizing properties in prolonged storage and therefore should not be stored for long periods before use in a coke oven.

78/ Naugle, B. W., Davis, J. D., and Wilson, J. E., Precision of Expansion Tests on Coal: Ind. Eng. Chem., vol. 43, 1951, pp. 2916-2922.

Generated on 2024-09-20 11:08 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Carbonization of Fine Coal in the Entrained and Fluidized State

Experimental work was continued on the carbonization of fine dried coal dusts in the entrained and fluidized state[79/80/81/] to study the factors affecting capacity of the process. Various tests were made on this unit to improve operation, and the capacity of the unit was increased materially as the factors affecting carbonization became better understood. The capacity was more than doubled by introducing air into the reactor to liberate heat by internal combustion. It was found that the tar yield was not affected by the addition of air. Further increase in capacity was attained by preheating the reactants.

A schematic engineering design of a large plant proportioned to carbonize approximately 30 tons of dried dust per hour was made, and the engineering of this unit for installation at Rockdale, Tex., during 1954 was begun.

Production of Special Carbons by the Carbonization of Noncoking Coals

The market for special metallurgical carbons in the West is expanding rapidly, owing primarily to the growing electrochemical industry in this area. Particularly, the phosphorus industry in Idaho will require large quantities of carbon to meet its expanding program. This industry has ordinarily used either coke breeze or petroleum coke, but the supply of these materials is limited since they are both byproducts. The expanding demand must be met by new sources that produce suitable carbons as primary products. It appears unlikely that existing or contemplated byproduct-coke plants can supply enough breeze at an attractive enough price to meet the new market demands.

As little research on the properties of carbons suitable for electric-furnace use has been conducted by the industry, complete specifications have not been established. However, the cokes generally used are sized to about 1/8- to 1/2-inch, contain about 3 to 5 percent of volatile matter, and do not produce condensable tars when heated to high temperatures in the electric furnaces.

To explore the application of the extensive deposits of cheap, noncoking, subbituminous coals in southwestern Wyoming to this problem, the Bureau of Mines, in cooperation with the Kemmerer Coal Co., is making laboratory studies of these coals. It was found that 3 to 5 percent volatile chars can be produced by carbonization at 1,250° to 1,450° F. and that chars produced above 1,300° F. are devolatilized to such an extent that they do not yield condensable tars when reheated to high temperatures.

Because of these promising laboratory studies, the Kemmerer Coal Co. is building a pilot plant designed to produce 150 tons of char per day by carbonizing lump coal in continuous vertical retorts. This plant is being built to supply enough char for full-scale industrial tests, and operation of the plant will be studied by the Bureau.

79/ Chemical Week, Tar and Char, Power Too: Vol. 69, No. 7, Aug. 18, 1951, pp. 25-26.

80/ Chemical Engineering, Lignite Process Hits the Mark: Vol. 58, No. 9, September 1951, pp. 219, 222.

81/ Parry, V. F., Coal and Char for Power Production: Proc. 4th Conf. Coal Research, Inc., Centralia, Wash., Dec. 7 and 8, 1951, pp. 48-50.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Gasification of Lignite

In the investigation of the continuous gasification of lignite, the gasification characteristics of different lignites under identical operating conditions were determined in the externally heated annular retort at the Bureau's Lignite Pilot Plant, Grand Forks, N. Dak. Lignites from 6 mines in North Dakota and 1 mine in Saskatchewan, Canada, were tested. In this experiment, the seventeenth in the series, slightly over 10 million cubic feet of gas was produced from 219 tons of lignite in 974 hours of operation, the longest test in the history of the project. No difficulty was experienced with the gasifier, which proved that this type of gas generator can be operated over an extended period.

With comparable operating conditions, the various lignites displayed different gasification characteristics with respect to gas yield and percentage of gasification. The gas yield per ton of natural lignite ranged from 38.4 to 55.3 thousand cubic feet and from 34.4 to 51.8 thousand cubic feet at the 450- and the 550-pound-per-hour rates of feed. The hydrogen - carbon monoxide ratio of the product gas varied from 2.12 to 3.77 and from 2.27 to 3.92 at the respective rates of feed.

An estimate of the probable life of the chromium-nickel-type 310-alloy reaction tube, based on examination of the possible influence of the ash and corrosion deposits, indicated that the life of the tube would be 33,000 and 108,000 hours as far as corrosion of the chromium and nickel, respectively, is concerned. The estimate is based on the loss of only 10 percent of the component present. In previous cost estimates it was indicated that a tube life of only 10,000 hours would be considered satisfactory.

Underground Gasification

Gasification of coal in place underground has been proposed for many years as an alternative to mining and subsequent processing of coal in surface installations. Development of a successful method may permit more economical utilization of the coal, either as chemical "building blocks", or as energy; it may permit exploitation of unminable, thin, or dirty beds; and it may reduce or eliminate hazards to personnel that occur in conventional mining.

The Bureau of Mines and the Alabama Power Co. have cooperated since 1947 in field-scale trials of underground gasification processes at Gorgas, Ala.82/83/84/85/ The Sinclair Coal Co. has participated in several of the more recent trials.

82/ Elder, J. L., Fies, M. H., Graham, H. G., Montgomery, R. C., Schmidt, L. D., and Wilkins, E. T., The Second Underground Gasification Experiment at Gorgas, Ala.: Bureau of Mines Rept. of Investigations 4808, 1951, 72 pp.

83/ Bureau of Mines, Synthetic Liquid Fuels. Annual Report of the Secretary of the Interior for 1951. Part I. - Oil from Coal: Rept. of Investigations 4865, 1952, pp. 74-79.

84/ Elder, J. L., Graham, H. G., Capp, J. P., and Eddy, W. H., The Underground Gasification of Coal: Military Eng., vol. 43, No. 296, part I, November-December 1951, pp. 398-400.

85/ Fies, M. H., and Elder, J. L., Laboratory and Field-Scale Experimentation on the Underground Gasification of Coal: Proc. United Nations Sci. Conf. Conservation and Utilization of Resources. Vol. III, Fuel and Energy Resources, United Nations Dept. of Economic Affairs, New York, 1951, pp. 144-150.

Generated on 2024-09-20 11:15 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:19 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

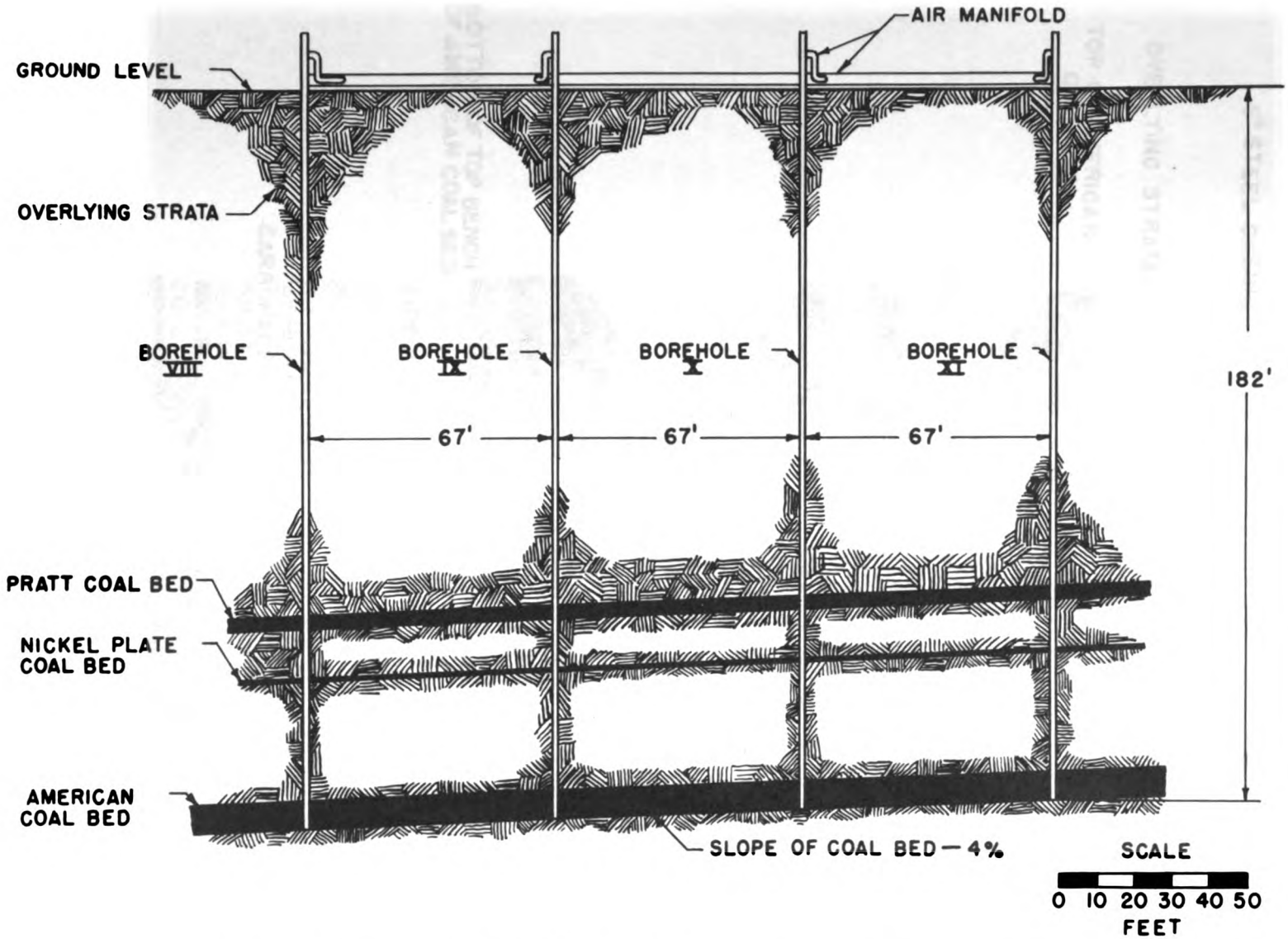

Figure 14. - Vertical section of electrolinking underground gasification experiment.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

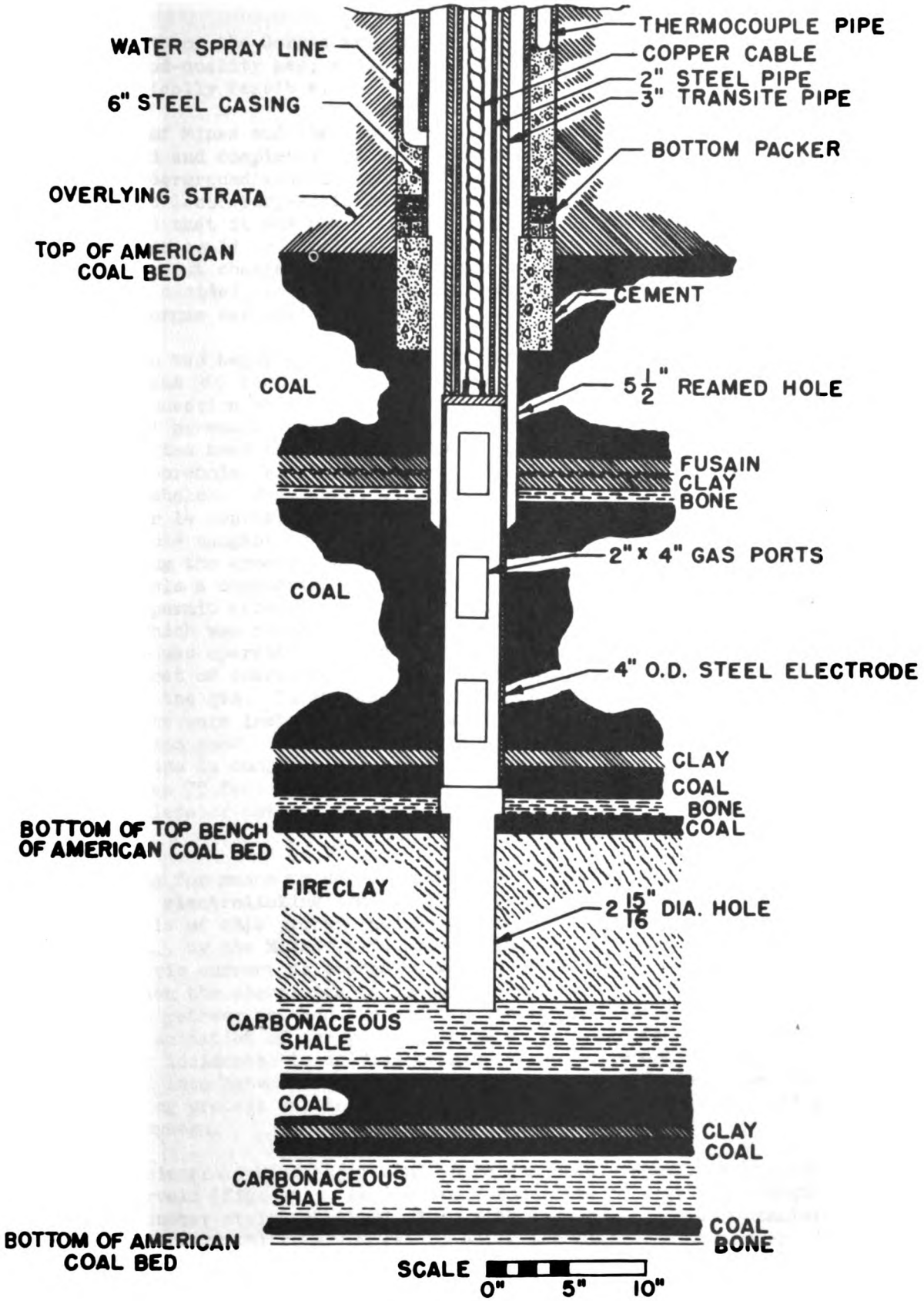

Figure 15. - Installation of electrode in coal bed.

Generated on 2024-09-20 11:19 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The objective of the Gorgas trials has been to develop a method that will assure production of good-quality gas; and, concurrently, to further refine the method to render it economically feasible.

The Bureau of Mines and the Alabama Power Co., during the first part of 1947, jointly conducted and completed, under a cooperative agreement, a small, field-scale experiment in underground gasification at Gorgas, Ala. The Bureau of Mines, in addition, carried out laboratory-scale investigations at Morgantown, W. Va. This preliminary work showed that it was not difficult to maintain coal combustion underground, that coal in place could be completely gasified, and that the high temperatures developed brought about changes in the overlying strata that appeared favorable to the process. It was decided, as a result of this work, that further investigation was warranted, and Gorgas was again chosen as the site.

Construction was begun on the second Gorgas experiment in 1948, and 1,295 feet of double entry and 300 feet of single entry were driven in the Pratt coal bed from its outcrop. Connection between the entries and the surface was made by large-diameter vertical boreholes spaced at 300-foot intervals along the entries. A seal wall was constructed near the outcrop. The coal was gasified by igniting it near the bottom of a borehole, blowing air in at this borehole, and taking gas off at one of the other boreholes. The 300-foot length of single entry was operated as a gasification unit for 14 months, after which another unit was developed by drilling an additional borehole tangent to the combustion face. In all, the system was operated 22 months. During the greater part of the time incombustible gas was produced, but for short intervals a combustible gas was recovered. The use of relatively wide entries did not permit effective control of the contact between the air and the combustion face, which was necessary to maintain production of good-quality gas. At times the system was operated at high gas temperatures at the outlet, and a large portion of the heat of combustion of the coal burned was brought to the surface as sensible heat of the gas. During another phase of the experiment, aircraft-type supercharger units were installed and operated by the hot gas under pressure issuing from the combustion zone. This qualitatively demonstrated the feasibility of operating a gas turbine in conjunction with an underground gasification plant. Coal was consumed as far as 75 feet from the wall of the nearest entry. It was found possible to create new inlets or outlets by drilling additional boreholes near the combustion face.

In searching for means to correct the deficiencies of the entry system, the process known as electrolinking came to the attention of the Bureau engineers. Small-scale field trials of this process had been conducted between September 1947 and June 1951 at Hume, Mo., by the Missouri School of Mines and the Sinclair Coal Co. In this process an electric current is passed between two electrodes embedded in the coal. Coal lying between the electrodes is heated and carbonized by the action of the current, creating a pathway between the electrode holes with fissures in the incandescent coke. The condition of the pathway is very favorable to gasification with air, and the cavities incidental to driving entries are not present. A cooperative agreement was entered into between the Bureau of Mines and the Sinclair Coal Co. whereby the electrolinking process was to be studied at Gorgas and was to be used to develop a gasification system.

The first electrolinking experiment at Gorgas used 4 electrodes placed in line at 67-foot intervals (fig. 14). An electrode consisted of a 24-inch length of 4-inch-outside-diameter stainless-steel pipe, with 6 2- by 4-inch rectangular ports cut in its walls (fig. 15) to allow gas to enter the electrode and escape into the hole above it. The electrode was inserted for 17 inches of its length in a closely fitting hole in the coal bed and was not permitted to contact the underclay. The

Generated on 2024-09-20 11:10 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

electrode was supported by a stem of 2-inch standard pipe enclosing a copper cable. The current-carrying capacity of the pipe and cable was equivalent to a 750-circular-mil copper cable. The electrodes were placed in boreholes drilled 10 inches in diameter to the top of the coal bed and cased with standard 6-inch pipe. Four-inch transite pipe with slip-on couplings separated the 2-inch pipe from the hole casing. A single-phase auto transformer supplied electric current at regulated voltages to pairs of electrodes.

On June 28, 1951, current was applied to boreholes IX and X. Initial resistance was 32 ohms, which decreased to 5 ohms in 16 hours. The following day potential was applied to boreholes VIII and XI. During 11 hours the resistance decreased from 44 ohms to 6.5. In these periods arcing occurred between the electrode stems and the hole casings, which nearly destroyed the electrical connection between the surface and the electrodes. Application of current was continued, but it is believed, that the greater part of the current passed through the casing to ground without reaching the coal bed. The section lying between boreholes VIII and IX was the only one rendered permeable enough to gas flow to allow gasification with air.

After application of current was discontinued, 44 days were required to open the underground passage between boreholes VIII and IX. The high resistance to gas flow was aggravated by the partial plugging of both boreholes by portions of the electrode stems and the transite insulation. New 6-inch boreholes were drilled adjacent to the electrode boreholes, following unsuccessful attempts to clean out the obstructions. Air was introduced at high pressures, and only a fraction was recovered as gas. The small amount of gas produced was of good quality and was enriched with coal-distillation products.

The succeeding 24 days were characterized by reduction in the resistance to flow and improved gas recovery. Gas recovery, in terms of air introduced, increased from 24 percent to 93 percent. The heating value of the gas increased; hydrogen content was 10.8 percent and carbon monoxide 16 percent during the final 8 days of this period. Air input averaged 306 std. c.f.m. at an average pressure of 51 p.s.i.g.

The section was operated 4 months longer. Gas quality decreased as contact between the coal and air became poorer. Meanwhile, two additional boreholes were drilled 152 feet apart, beyond borehole IX, and electrodes were placed in them. These holes were not cased below 35 feet depth, and no insulation was provided for the electrode stem. The electrodes were constructed as in the previous trial, but the stem size was increased to standard 4-inch pipe, and copper cable was eliminated.

In the first 56 hours when current was applied, the electrical impedence decreased from 36 to 3.8 ohms. Current was applied during an additional 64 hours, and impedance decreased further to 0.35 ohm. Large quantities of coal-distillation gas issued from the coal bed during the latter phase (fig. 16). After application of current was discontinued, it was found that the air-gas passageway was permeable enough to permit gasification with air. Accordingly, gasification was begun, and combustible gas with heating value ranging between 70 and 120 B.t.u. was produced.

The electrolinking method permits development of the gasification zone in a manner well suited to further gasification, whether with air, oxygen, or either combined with steam. No personnel is required to work underground. No large cavities are initially present. A considerable volume of rich coal-distillation gas is produced during the electrocarbonization phase.

Further experimentation is underway to determine:

Generated on 2024-09-20 11:08 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:13 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

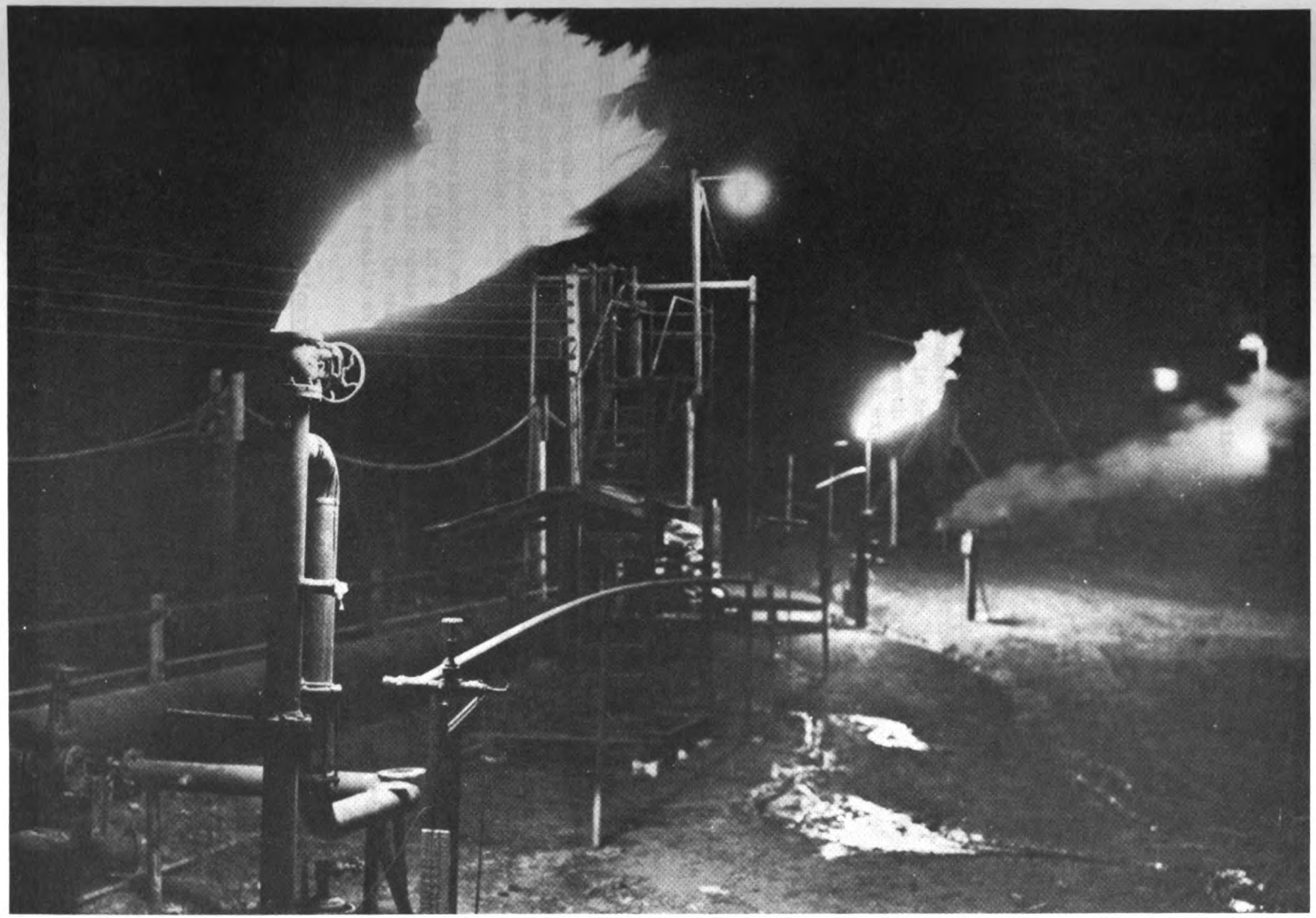

Figure 16. - Burning the gases produced in electrolinking gasification experiment.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

(1) The area of coal bed that may be gasified between two electrodes.

(2) The efficiency of coal utilization in the area mentioned above.

(3) The electrical and gasification characteristics of various electrode spacings.

(4) The economic characteristics of an integrated underground-gasification system using electrolinking and electrocarbonization as a means of obtaining a passage through coal.

Studies are continuing on the problems of air or gas leakage and the reduction of pressure drop through the system.

Liaison has been maintained with the trials conducted in other countries through mutually exchanged progress reports. In addition, Bureau of Mines personnel has visited experimental sites in Belgium and Morocco. For nearly 3 years an observer for the British Fuel Research Station was at Gorgas. The Gorgas site has been visited by men connected with experimentation in Belgium, France, and England and observers from other countries.

The First International Conference on the Underground Gasification of Coal was held at Birmingham, Ala., and at Gorgas February 12, 13, and 14, 1952. It was attended by representatives of many foreign countries, as well as American representatives of industry, educational institutions, and the Bureau of Mines.

RESEARCH ON THE PRODUCTION OF SYNTHESIS GAS

Gasification of Pulverized Coal

Laboratory-Scale Experimentation

A program of laboratory-scale pilot plant investigation of the gasification of powdered coals in entrainment in oxygen and superheated steam showed that the operating results obtained by gasifying coals at feed rates up to 55 pounds per hour with process variables under precise control were closely reproducible.86/

The experimental work proved that, contrary to some previous beliefs, all coals do not gasify alike in a generator of given design but differ in their behavior. Young high-volatile coals, for example, were found to gasify easier than high-rank, low-volatile coals. On the other hand, high-ash or high-sulfur coals were gasified in entrainment as easily as high-grade coals, whether the coal was strongly coking or noncoking.

Pilot-Plant Scale Gasification at Atmospheric Pressure and High Pressure

Processes developed in cooperation with the Babcock & Wilcox Co. for complete gasification of coal, using steam and oxygen, showed that economically, as well as technically, satisfactory plants operating both at low pressure (under 5 pounds per square inch) and at higher pressure (up to 500 pounds per square inch) should prove feasible.

86/ Sebastian, J. J. S., Powdered Coal Gasification - Effect of Variables: Ind. Eng. Chem., vol. 44, 1952, pp. 1175-1184.

Generated on 2024-09-20 11:10 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The low-pressure gasification unit[87/88] (450 pounds of coal per hour) was operated for over 25 test runs. Coal from the Sewickley bed, Monongalia County, W. Va., ground to 70 percent through a 200-mesh screen, was gasified with very good results. The low oxygen requirement per 1,000 std. c.f. of synthesis gas demonstrated the promise of this method. The coal requirement at 85 percent of carbon gasified was low per unit of synthesis gas produced. Slagging worked well, showing the applicability of the process to a wide range of coals. The success of this process is indicated further by the increasing interest shown by several industries in its application to their requirements.

The test work on the high-pressure gasification unit included several tests at 100, 250, and 300 pounds per square inch reactor pressure. The results showed that very large throughputs, in pounds of coal per hour per cubic foot of reactor volume, will be obtained in these units. Table 5 gives some average results from test runs at 100, 250, and 300 pounds per square inch.

TABLE 5. - Typical performance of pressure gasifier operating on pulverized Sewickley-bed coal

Gasifier static pressure, p.s.i.g.	100	250	300
Raw coal rate.....lb./hr.	413	614	919
Steam-oxygen inlet temp. .....°F.	517	535	659
Coal-inlet temp. .....do.	295	300	295
Oxygen input per lb. raw coal.....std. c.f.	9.3	9.0	8.8
Steam input per lb. raw coal.....lb.	0.30	0.29	0.29
Product-gas analysis, corrected for inert "feed gas" with coal and "purge" gas to gasifier, percent:			
CO_2.....	7.9	8.6	8.9
H_2.....	34.0	35.2	35.4
CO.....	54.9	52.5	52.4
CH_4 + Ill.	0.9	1.5	1.2
(CO + H_2) flow, corrected for inert feed gas and purge gas.....std. c.f.	11,200	15,900	24,500
Total carbon in coal gasified.....percent	90	82	86
Materials requirements per 1,000 std. c.f. of (CO + H_2):			
Coal.....pounds	37	39	37
Process oxygen.....std. c.f.	345	350	330
Coal throughput.....lb./(hr.) (cu.ft. of gasifier volume)	125	425	620

The high-pressure unit will be ready for tests at 450 pounds per square inch reactor pressure in the fall of 1952. The test work on both gasification pilot plants has demonstrated the great importance of correct design for the nozzles used to introduce the reactants. The design of the nozzle is in turn affected by the construction or geometry of the gasification chamber and the physical nature of the reactants, for example, fineness of coal and temperature at which reactants are charged.

87/ Bureau of Mines, Synthetic Liquid Fuels. Annual Report of the Secretary of the Interior for 1951. Part I. - Oil from Coal: Rept. of Investigations 4865, 1952, pp. 67-71.

88/ Schmidt, L. D., Synthesis Gas from Pulverized Coal, Oxygen, and Highly Superheated Steam is Produced in Pilot Plant: Am. Gas Jour., vol. 175, July 1951, pp. 10-14.

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

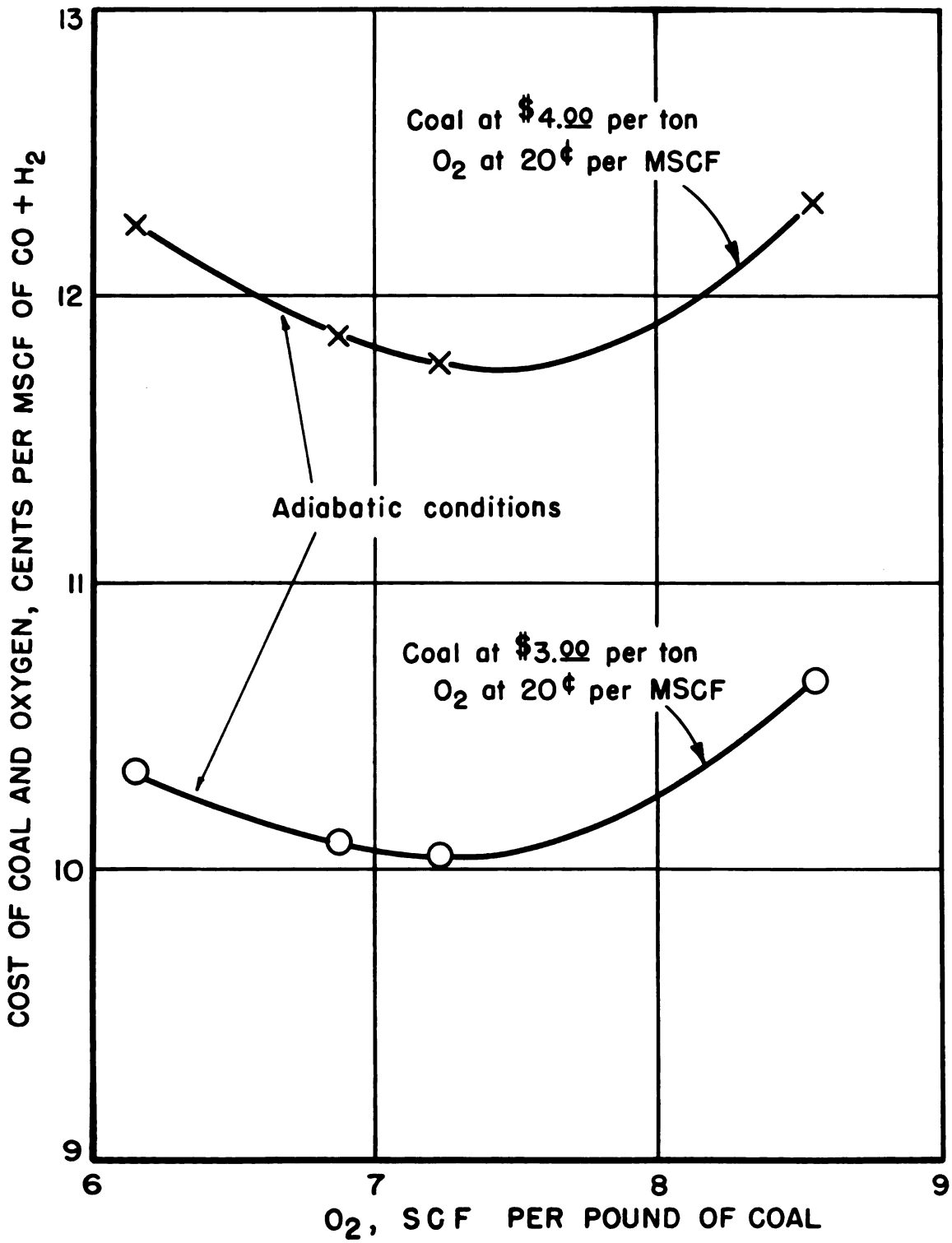

Figure 17. - Effect of oxygen-coal ratio on cost of oxygen and coal per 1,000 std. c. f. of carbon monoxide and hydrogen produced in adiabatic vortex reactor 24 inches in diameter and 36 inches deep. Feed rate - 100 pounds coal per hour, 55 pounds of steam per hour. Oxygen and steam preheated to 1300°F.

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Although results obtained to date have been very encouraging and show the basic soundness of the overall method, an extended program of investigation is in progress to determine the optimum designs for various fuels and gasification units.

Gasification by the Vortex Principle

A considerable amount of experimental and developmental work was conducted on the continuous suspension gasification of low-cost, noncaking bituminous coal with steam and oxygen in a vortex reactor.89/ Tests were made to determine the effect of reactor geometry, the material feed rates, and the method of admitting oxygen upon the quantity and the quality of gas produced and the efficiency of carbon conversion. Significant findings of the investigation included a method for calculating the performance of an "adiabatic" reactor, that is, one without heat losses, and a relationship between the ratio of oxygen to coal in the feed and the cost of these materials per unit volume of make gas. These two results are important in assessing the cost of operation of a commercial-size unit.

Figure 17 shows the effect of the oxygen-coal ratio on the cost of coal and oxygen in the particular reactor used in the studies. The figure shows that, for adiabatic conditions, there is a ratio at which the cost is a minimum, depending upon the unit price of the coal.

Feeding of Pulverized Coal

To deliver coal at uniform rate to a pulverized-coal gasifier a coal feeder is used that operates by causing a partly settled mixture of coal and air to flow through a tube from a fluidized bed of pulverized coal. To predict the rate of coal delivery, tests were made to determine the pressure drop of the coal-air mixture flowing through the tube in terms of the weight rate of coal flow, the ratio of coal to conveying air, and the tube diameter.90/ The results were correlated in the form of two empirical equations, which give the pressure drop for the flow of mixtures of air and coal through horizontal tubes and in the ratio of approximately 200 pounds of coal per pound of air. So far as is known, these are the first pressure-drop measurements on mixtures using such a high solid-gas ratio.

Synthesis Gas Purification and Analysis

A method was studied for determining low concentrations of oxygen.91/ The method adopted was a colorimetric procedure that is described in the literature, but the sensitivity and accuracy were increased by measuring the color intensity with a spectrophotometer rather than by visual comparison using Nessler tubes.

Work is progressing on adapting the methylene-blue method to the determination of mercaptan sulfur. Spectrophotometric methods for both styrene and nitric oxide determination were developed.

89/ Elliott, M. A., Perry, H., Jonakin, J., Corey, R. C., and Khullar, M. L., Gasification of Pulverized Coal with Oxygen and Steam in a Vortex Reactor: Ind. Eng. Chem., vol. 44, 1952, pp. 1074-1082.

90/ Albright, C. W., Holden, J. H., Simons, H. P., and Schmidt, L. D., Pressure Drop in Flow of Dense Coal-Air Mixtures: Ind. Eng. Chem., vol. 43, 1951, pp. 1837-1840.

91/ Bureau of Mines, Synthetic Liquid Fuels, Annual Report of the Secretary of the Interior. Part I. - Oil from Coal: Rept. of Investigations 4865, 1952, p. 72.

Generated on 2024-09-20 11:13 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

A reliable gravimetric method for moisture determination was developed and used to determine the accuracy of the methods used for undecomposed steam calculation on the larger atmospheric pressure gasifier. The percentage of steam decomposition, as calculated from these determinations, was in very good agreement with that calculated from material balances using the test-run data.

A study was made of the feasibility of adjusting the ratio of hydrogen to carbon monoxide in synthesis gas using the standard shift reaction catalyst.92/ Under certain conditions of gasification the ratio of hydrogen to carbon monoxide might be higher than that required for hydrocarbon synthesis. The kinetics of the reaction was studied, and a rate equation was obtained. The constants of this equation were evaluated at 1,000° F., and a probable mechanism for the reaction was postulated. The results of the investigation show that this method of adjusting the synthesis-gas composition is feasible but that its use would depend upon the economic advantage of employing a large excess of superheated steam in the coal-gasification step.

For dust removal the use of a moving granular bed is being investigated. The fouled filtering material is intermittently or continuously removed, washed, and reused. Unlike other dust-removing devices this equipment has great flexibility. It is believed that, by varying the particle size of filtering material, it will be possible to obtain nearly any desired gas purity from crude gas. With very fine particles, however, dropping and washing of the filtering material will probably present new problems.

In a study of the disposal of solid residues from gasification operations, it was found that certain properties of the light dust suggested its use as a substitute for carbon black. Investigation showed that it could be used as a rubber filler, but its reinforcing power is low.

Bench-scale experiments were continued on the simultaneous removal of hydrogen sulfide and organic sulfur from synthesis gas, using a copper-chromium-vanadium catalyst at elevated pressures.

Numerous pilot-plant runs were made during the year to remove the hydrogen sulfide and carbon dioxide from synthesis gas simultaneously and to study the selective absorption of hydrogen sulfide from a gas containing relatively high amounts of carbon dioxide. Among the selective absorbents studied were triethanolamine, tripotassium phosphate, and Alkacid "DIK". The scrubbing solutions studied for the simultaneous removal of hydrogen sulfide and carbon dioxide included diethanolamine, hot potassium carbonate, and Alkacid "M".

Many operating data were obtained, so that cost estimates could be made on the purification of gases having various compositions. A rather extensive program was carried out that included the study of various solution concentrations, the effect of varying concentrations of carbon dioxide and hydrogen sulfide in the raw gas on solution circulating rates, the effect of organic sulfur compounds on the scrubbing solution, etc.

Pilot-plant runs were continued throughout the year on the removal of organic sulfur by activated carbon and the simultaneous removal of hydrogen sulfide and organic sulfur using a copper-chromium-vanadium catalyst.

92/ Barkley, L. W., Corrigan, T. E., Wainwright, H. W., and Sands, A. E., Catalytic Reverse Shift Reaction: Ind. Eng. Chem., vol. 44, 1952, p. 1066-1071.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

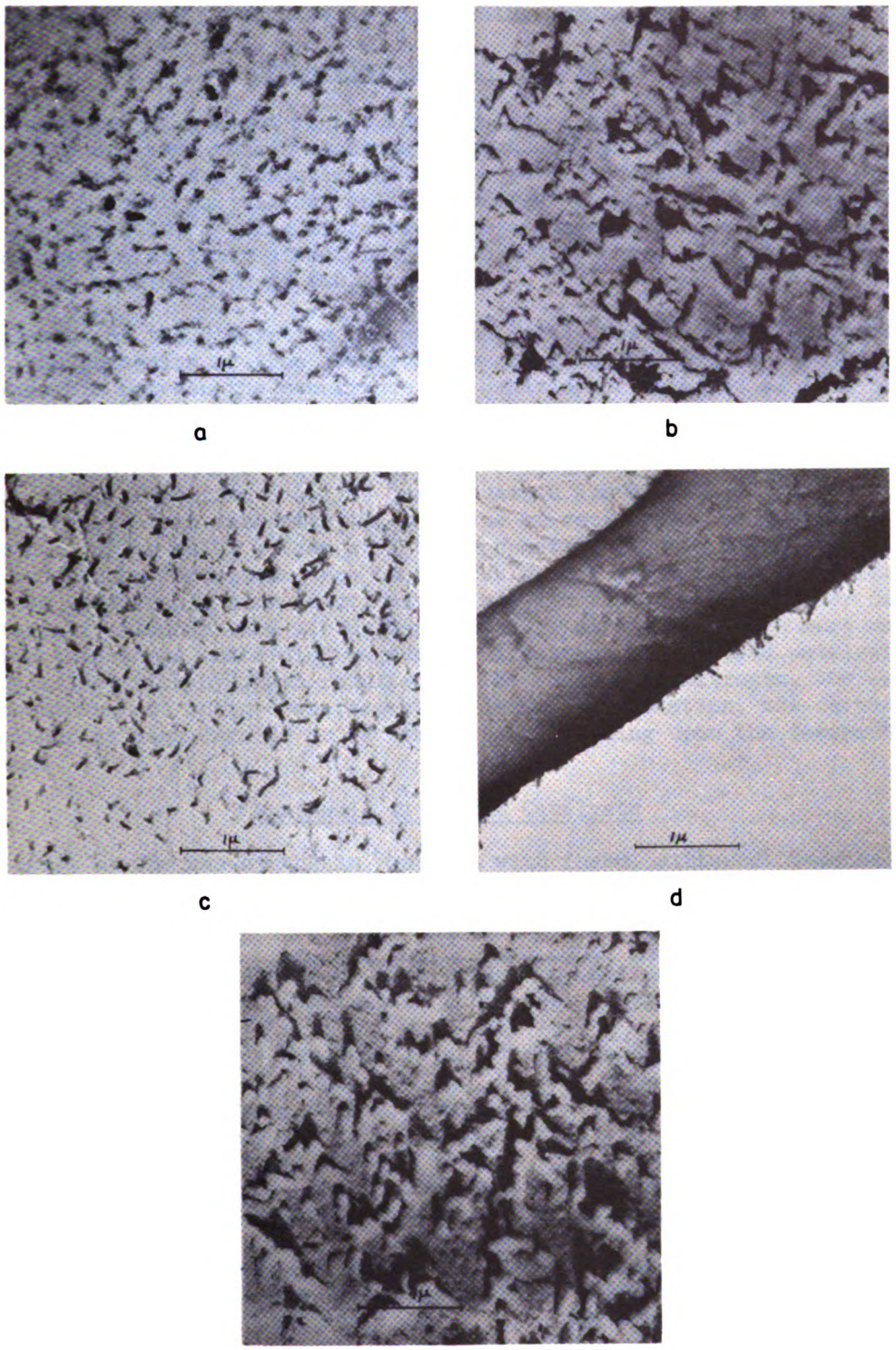

Figure 18. - Electron micrographs of various replicas of reduced fused iron catalyst. a-Unshadowed Formvar; b-Shadowed Formvar; c-Unshadowed silica; d-Folded silica replica; e-Shadowed silica.

Generated on 2024-09-20 11:16 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Properties of Iron Catalysts

When particles of a fused iron oxide catalyst are reduced with hydrogen, their external volume and area remain unchanged, but the total surface area is increased greatly as a result of the formation of a fine pore structure. Electron microscopic photographs of Formvar and silica replicas from surfaces of such reduced catalysts are shown in figure 18.[93] The microstructure of these surfaces is believed to be produced by pores, and their diameters (400 to 600 A) agree well with those estimated from adsorption studies (370 to 800 A).

The concept of the adsorption of gases on solids was further clarified.[94] Details of the poisoning of iron catalysts by chloride ions were described.[95] A correlation was made between the occurrence and behavior of carbides in iron catalysts and in martensite.[96]

A combination of chemical and X-ray analyses was used to follow the changes of composition of nitrided-iron catalyst during use in synthesis.[97] Iron nitride was slowly converted to iron carbonitride, the rate of replacement of nitrogen by carbon being somewhat faster at 21.4 than at 7.8 atmospheres. At the higher pressure, oxidation and carbon deposition were considerably more rapid in some nitrided catalysts. These undesirable side reactions varied with the type of promoter contained in the catalysts; alumina- and zirconia-promoted catalysts were much more resistant to oxidation than those containing magnesia. Treatment of the used catalysts (mainly iron carbonitride) with hydrogen resulted in the removal of nitrogen, whereas the carbon content was not changed appreciably. After hydrogenation, the carbidic carbon appeared either as Hägg carbide or as cementite, depending upon the temperature of the treatment.

Synthesis with Iron Catalysts

In a study of the gas-synthesis reaction with fused, sintered, cemented, and precipitated iron catalysts in laboratory-scale, fixed-bed reactors, several important variables of the Fischer-Tropsch synthesis were investigated.[98] To correlate

---

93/ McCartney, J. T., and Anderson, R. B., Electron Microscopic Replica Studies of Porosity in Fused Iron Catalysts: Jour. Appl. Phys., vol. 22, 1951, pp. 1441-1443.

94/ Hall, W. K., On Halsey's New Multilayer Adsorption Equation: Jour. Am. Chem. Soc., vol. 74, 1952, p. 1081.

95/ Hofer, L. J. E., Anderson, R. B., Peebles, W. C., and Stein, K. C., Chloride Poisoning of Iron-copper Fischer-Tropsch Catalysts: Jour. Phys. Colloid Chem., vol. 55, 1951, pp. 1201-1206.

96/ Hofer, L. J. E., and Cohn, E. M., Some Reactions in the Iron-Carbon System; Application to the Tempering of Martensite: Nature, vol. 167, 1951, pp. 977-978.

97/ Schultz, J. F., Seligman, B., Lecky, J., and Anderson, R. B., Studies of the Fischer-Tropsch Synthesis, XII. Composition of Changes of Nitrided Iron Catalysts During the Synthesis: Jour. Am. Chem. Soc., vol. 74, 1952, pp. 637-640.

98/ Anderson, R. B., Seligman, B., Schultz, J. F., Kelly, R., and Elliott, M. A., The Fischer-Tropsch Synthesis. Some Important Variables of the Synthesis over Iron Catalysts: Ind. Eng. Chem., vol. 44, 1952, pp. 391-397.

Generated on 2024-09-20 11:06 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

the results, an empirical equation was proposed by which the conversion of the synthesis gas ($1H_2$:1CO) is related to the hourly space velocity at which the gas is passed through the reactor and to the temperature in the reactor. This equation served as the basis for a mathematical expression of the activity of a catalyst, which was arbitrarily defined as the conversion of synthesis gas per unit volume of catalyst at a space velocity corresponding to 65-percent conversion of the gas and calculated at 240° C. Such activity values are experimentally reproducible to ± 10 percent.

An increase in pressure from 100 to 300 p.s.i.g. of synthesis gas resulted in an average increase of the activity by a factor of 1.8 to 3.3; the strong dependence of the synthesis on pressure is in marked contrast to the synthesis over cobalt catalysts. Although the activities of sintered fused (at 300 p.s.i.g.) and nitrided fused iron catalysts remained essentially constant during some 10 weeks of testing, the precipitated and the fused catalysts (at 100 p.s.i.g.) lost some activity during the tests. The product distribution did not vary uniformly with pressure. The average molecular weight of the condensed fraction (liquids and solids) decreased with pressure for the precipitated and sintered catalysts, but increased for the fused catalysts. The yield of oxygenated products increased with pressure, except for the nitrided catalysts, which yielded a large amount of oxygenates at both pressures.

The effect of particle size was tested with different mesh sizes of the same fused catalyst. The activity was strongly dependent on the size (and hence external area) of the particles, although a 40- to 60-mesh fraction showed a leveling off of activity as a function of particle size. It was estimated that a depth of only about 0.1 mm. from the surface of the catalyst particles is effective in the synthesis. The activity decreased with time. The variation in product distribution was apparently a function of the temperature of the synthesis only and independent of particle size.

Addition of about 0.4 weight-percent of potassium oxide produced maximum activity in the sintered, cemented, and probably also in the fused catalysts. With precipitated catalysts there was only a gradual increase of activity with increasing alkali content up to the maximum amount used, 0.75 percent of potassium oxide. In all cases, the rate of carbon deposition increased with alkali content. The average molecular weight and the amount of oxygenates in the products increased at least up to the optimum alkali content, whereas the usage ratios of synthesis gas (H_2:CO) decreased.

The usage ratios may exceed 1.5 at low fractional conversion; they decrease as more synthesis gas is consumed and again when the unused gas exceeds a certain ratio of hydrogen to carbon monoxide. The principal primary synthesis reaction probably produces water, and these variations in usage ratio result from the simultaneous occurrence of the synthesis and the water-gas shift reactions over iron catalysts.

The activity and selectivity of several iron catalysts showed remarkable changes as a result of the conversion of an iron catalyst into an iron nitride.99/ At 100 p.s.i.g. the initial activity (60 to 70) of nitrided fused catalysts was twice that of catalysts that were only reduced. Increasing the pressure to 300 p.s.i.g. more than doubled the activity. Sintered and precipitated catalysts also showed initial twofold activity (165 and 200 to 250, respectively) when nitrided, but these merged with the activity of the reduced catalysts after 4 to 5 weeks of synthesis (about 100 and 140 to 150, respectively). The wide variation of product distribution as a

---

99/ Schultz, J. F., Seligman, B., Shaw, L , and Anderson, R. B., The Fischer-Tropsch Synthesis. Effect of Nitriding on Three Types of Iron Catalyst: Ind. Eng. Chem., vol. 44, 1952, pp. 397-401.

Generated on 2024-09-20 11:07 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

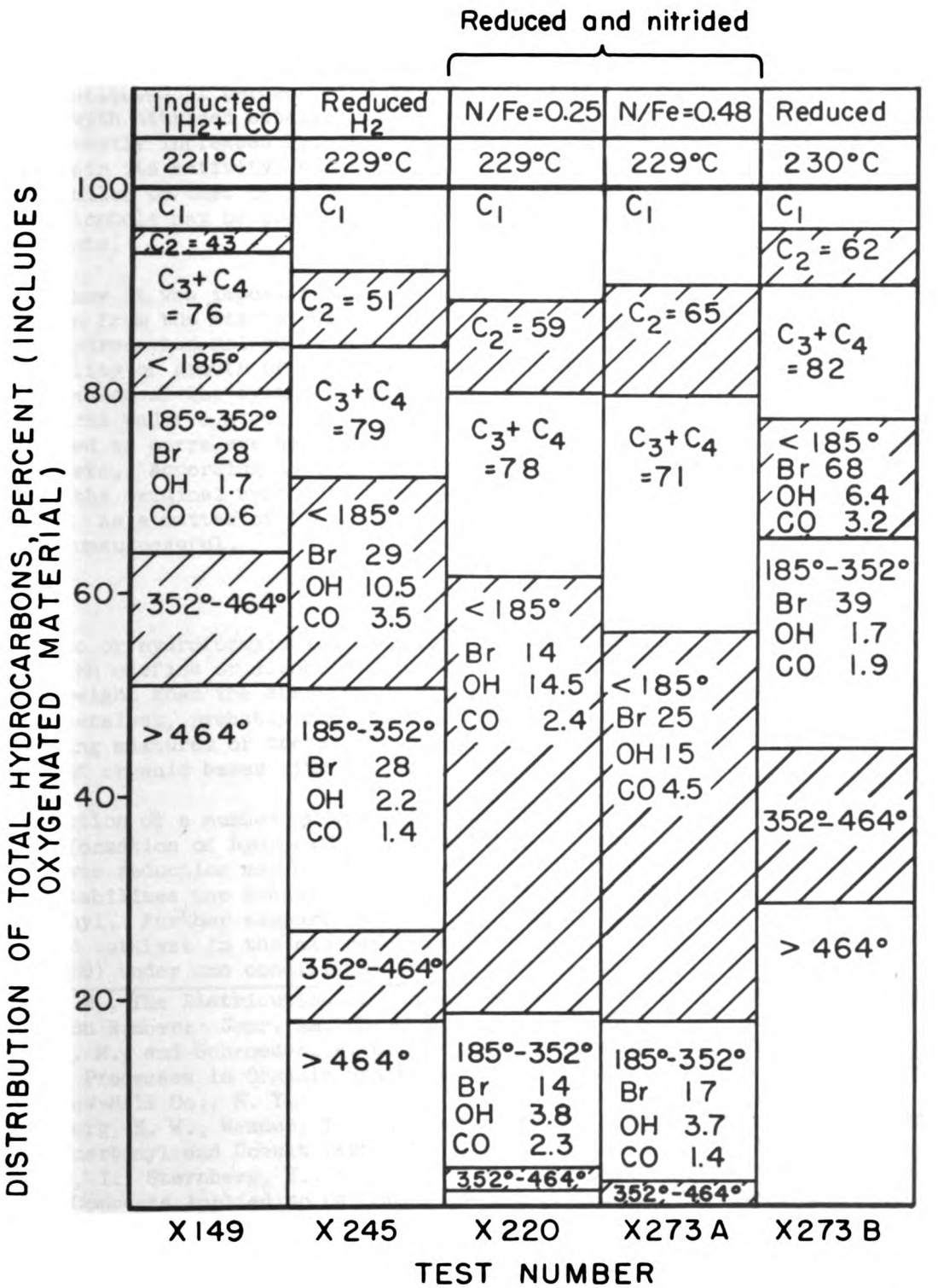

Figure 19. - Effect of pretreatments of precipitated catalyst P 3003.24 on the composition of products obtained from it.

Generated on 2024-09-20 11:14 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

function of nitrogen content is illustrated in figure 19, which shows the products from six tests of the same precipitated catalyst, each batch of catalyst having received a different conditioning treatment before synthesis. The percentage of olefins is indicated by the double-bond symbol (=), Br indicates bromine number, OH weight-percentage of hydroxyl group, and CO weight-percentage of carbonyl group present as aldehydes, ketones, and acids. The fraction of product boiling above 464° C. constituted 51 percent with inducted ($1H_2$:1CO) catalyst (X-149) but was negligible with nitrided catalyst (X-220 and 273A). The yields of oxygenated products were greatly increased by nitriding. Reduction of a nitrided catalyst (X-273A) did not impair its activity, but removal of nitrogen resulted in a selectivity (X-273B) similar to that of an originally reduced catalyst (X245). Thus, large yields of alcohols may be produced with long-lived, mechanically stable, nitrided iron catalysts.

Up to now it was impossible to correlate large amounts of data on the product distribution from the Fischer-Tropsch synthesis. An extension of the theory of the growth of hydrocarbon molecules during their contact with the catalyst showed that the probability of growth of the carbon chain on cobalt or iron, although dependent on the variables of the synthesis, is approximately constant for the liquid and solid products under a given set of reaction conditions.1/ This probability factor has been used to correlate data obtained at a number of laboratories with cobalt and iron catalysts. According to this mathematical development, not more than 29 weight-percent of the original synthesis product can be in the range of boiling points of diesel oil. As a matter of fact, attempts in German laboratories to increase this yield were unsuccessful.

The Oxo Reaction

The oxo or hydroformylation reaction is the combination of carbon monoxide and hydrogen with olefins or alcohols, usually yielding oxygenated products of higher molecular weight than the starting material.2/ The reaction proceeds in the presence of cobalt catalyst, probably cobalt hydrocarbonyl or dicobalt octacarbonyl. A method for analyzing mixtures of these cobalt compounds was developed,3/ and the reaction mechanism of organic bases with dicobalt octacarbonyl was described.4/

Subjection of a number of aromatic alcohols and ketones to oxo conditions resulted in formation of hydrocarbons rather than the usual oxygenated materials.5/ This complete reduction may be attributed to the fact that the carbon adjacent to the ring stabilizes the substituted benzyl radical, which then reacts with cobalt hydrocarbonyl. Further support was obtained for the theory that cobalt hydrocarbonyl is the acid catalyst in the oxo reaction.6/ When pinacol was treated with synthesis gas ($2H_2$:1CO) under oxo conditions, four compounds more volatile than the starting

1/ Manes, M., The Distribution of Liquid and Solid Fischer-Tropsch Hydrocarbons by Carbon Number: Jour. Am. Chem. Soc., vol. 74, 1952, pp. 3148-3151.

2/ Orchin, M., and Schroeder, W. C., Hydroformylation (Oxo Reaction), Chapter IX, Unit Processes in Organic Synthesis (P. H. Groggins, ed.): 4th ed., 1952, McGraw-Hill Co., N. Y.

3/ Sternberg, H. W., Wender, I., and Orchin, M., Analysis of Mixtures of Dicobalt Octacarbonyl and Cobalt Carbonyl Anion: Anal. Chem., vol. 24, 1952, pp. 174-176.

4/ Wender, I., Sternberg, H., and Orchin, M., The Chemistry of Metal Carbonyls, I. New Concepts Applied to Carbonyls of Cobalt: Jour. Am. Chem. Soc., vol. 74, 1952, pp. 1216-1219.

5/ Wender, I., Greenfield, H., and Orchin, M., Chemistry of the Oxo and Related Reactions, IV. Reductions in the Aromatic Series: Jour. Am. Chem. Soc., vol. 73, 1951, pp. 2656-2658.

6/ Wender, I., Metlin, S., and Orchin, M., Chemistry of the Oxo and Related Reactions, V. Acid Catalysis with Pinacol: Jour. Am. Chem. Soc., vol. 73, 1951, pp. 5705-5706.

Generated on 2024-09-20 11:18 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

material were recovered and identified. The origin of these products is consistent with the formation of a common carbonium-ion intermediate produced from pinacol by acid catalysis.

SYNTHETIC LIQUID FUELS BY COAL HYDROGENATION: RESEARCH AND DEVELOPMENT

Kinetics of Coal Hydrogenation

Conversion of Asphaltene

Asphaltene, a material that is soluble in benzene but not in n-hexane, appears to be an intermediate product in the conversion of coal to oil. Its presence in the end product is undesirable, and knowledge of the conditions for its elimination will make it possible to develop better hydrogenation processes. An autoclave study was therefore made with a material containing 93.8 percent of asphaltene obtained by hydrogenation of Pittsburgh-bed coal.7/ This was hydrogenated at 400° to 430° C., at 1,250 or 2,500 p.s.i.g. initial cold hydrogen pressure (corresponding to about 3,000 or 6,000 p.s.i.g. initial pressure at reaction temperature), and for 0 to 3 hours; stannous sulfide plus ammonium chloride was the catalyst. Under given conditions the rate of hydrogenation of asphaltene to oil was directly proportional to the amount of remaining asphaltene, that is, of first order with respect to asphaltene. This rate changed considerably with variation of temperature, indicating that the rate-determining step is a chemical reaction rather than, for example, diffusion of hydrogen through a boundary film. Furthermore, as the rate of change did not obey the Arrhenius equation, hydrogenation probably occurs by more than one chemical reaction. At constant temperature, the rate varied linearly with hydrogen pressure, so that the necessity for high pressures of hydrogen is due to kinetic and not thermodynamic reasons. Within the temperature region of this study, 91 percent of the hydrogenated asphaltene appeared as oil.

Conversion of Anthraxylon

The information on the conversion of asphaltene was used to interpret the results obtained in an autoclave study of the hydrogenation of hand-picked anthraxylon from Pittsburgh-bed coal. The rate of conversion of coal to liquid and gaseous product was directly proportional to the amount of unreacted coal remaining minus 1.6 percent of refractory organic material that could not be liquefied even after long reaction times. The fraction of the coal converted to asphaltene decreased from 94 percent at 400° C. to 88 percent at 440° C. At the lower temperatures, most of the hydrogen consumed was used to convert coal to asphaltene; at the higher temperatures, increasing amounts of gas were formed, and, correspondingly, more hydrogen was used. The overall reaction appeared to be the result of two consecutive first-order reactions, coal being converted to asphaltene and then asphaltene to oil. To minimize the consumption of hydrogen (the production of which constitutes a major portion of the cost of the hydrogenation process) and the production of gaseous hydrocarbons (which are less valuable than the liquid products), hydrogenation of coal should probably be carried out in 2 stages, corresponding to the above 2 reactions, under the respective optimum conditions for each of these reactions.

7/ Weller, S., Pelipetz, M. G., and Friedman, S., Kinetics of Coal Hydrogenation - Conversion of Asphalt - Conversion of Anthraxylon: Ind. Eng. Chem., vol. 43, 1951, pp. 1572-1575 and 1575-1579; also Documents 3117 and 3118 of Am. Documentation Inst.

Generated on 2024-09-20 11:09 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:07 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

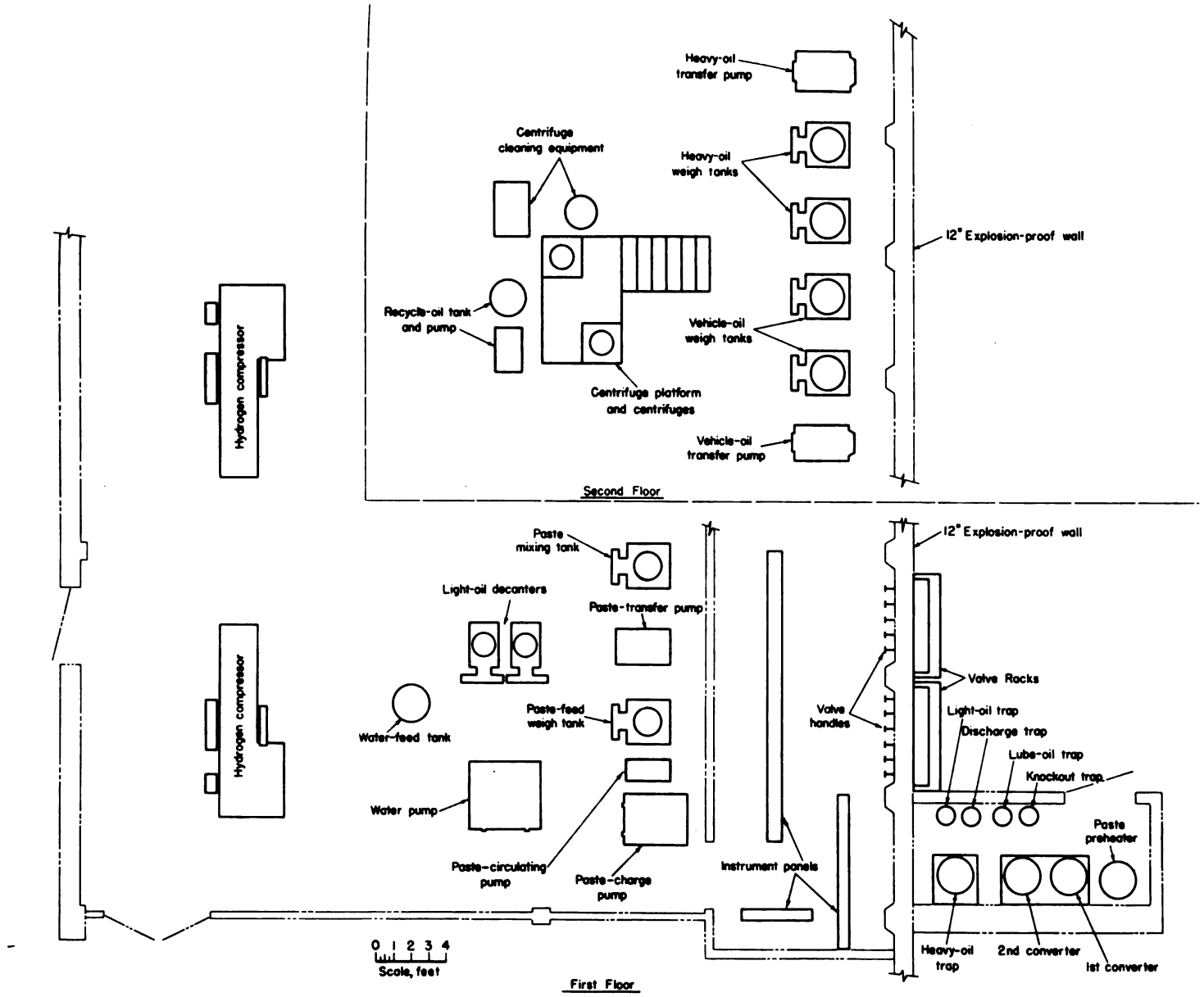

Figure 20. - Equipment layout of experimental coal-hydrogenation plant.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Pilot-Plant Operations

Hydrogenation of Coal

Some high-pressure equipment, consisting of two types of valves and a head pump, developed at the Bruceton laboratories was installed in the coal-hydrogenation pilot plant.8/ The equipment layout of the plant is shown in figure 20.

The plant was used for five operating runs, each comprising a number of tests with mixtures of coal and oil, in which high-volatile C bituminous coal of the Rock Springs bed, Wyo. was hydrogenated at 460° C. and with 3,500 p.s.i.g. pressure of hydrogen. In all cases, 90 percent of the coal powder passed through a 200-mesh sieve. Catalyst, when used, was either added in powdered form (tin sulfide with iodoform or ammonium chloride, zinc with ammonium chloride) to the 35 coal:65 oil paste or impregnated in the coal (ferrous sulfate, nickelous chloride) before pasting. To obtain reliable comparative data on the activities of these catalysts, the plant was thoroughly cleaned before each run, parts of the tubing were replaced, and new liners were installed in the converters.

Under the experimental conditions tin sulfide yielded the best conversion of coal to asphaltene; ferrous sulfate and nickelous chloride were almost as effective, whereas zinc powder was inferior to these catalysts. Nickel and tin were virtually equivalent and substantially better than iron and zinc for converting asphaltene to heavy fuel oil and middle oil. The results were quite similar to those obtained in batch autoclave tests, proving that the latter furnish a reliable and relatively inexpensive method for the evaluation of potential catalysts for coal hydrogenation.

The use of lower pressures of hydrogen, although not necessarily decreasing the cost of the process substantially, would make possible the use of standard equipment, such as series 150 piping, for much of the plant and of welded rather than forged vessels. Since 1,500 p.s.i.g. represents the upper limit of pressure at which easily available structural material can be employed, a series of operations was carried out at this pressure with Rock Springs, Wyo., coal.9/ The catalysts were impregnated on the coal from aqueous solutions of the following salts: Nickelous chloride, stannous chloride, ferrous sulfate, and ammonium molybdate. To obtain optimum activity with the last-named catalyst, the alkalinity of the coal was partly neutralized by adding sulfuric acid to the ammonium molybdate solution.

For the conversion of coal to asphaltene, the activity of the catalysts decreased, in order, molybdenum, tin, nickel, and iron. The relative effectiveness of these catalysts for the production of oil from asphaltene varied in the same order, except that nickel and tin were approximately equal. Molybdenum yielded the best heavy oil, which had a lower viscosity, contained less benzene-insolubles, asphaltene, and sulfur, and contained a larger amount of hydrogen than the oils obtained with the other catalysts. The yields from a ton of coal included about 3 barrels of fuel oil, 3,500 cubic feet of hydrocarbon gas, and possibly 35 pounds of recoverable byproducts (ammonia, hydrogen sulfide, and tar acids and bases). Although these yields, as well as the hydrogen consumption, are not as favorable as those at higher pressures, the greater simplicity of construction of such a plant may outweigh the disadvantages of the present high-pressure process; furthermore, future development of more active catalysts might make this development even more attractive.

8/ Kandiner, H. J., Hiteshue, R. W., and Clark, E. L., Catalyst Evaluation and Middle-Oil Preparation in an Experimental High-Pressure Coal Hydrogenation Plant. Parts I and II: Chem. Eng. Prog., vol. 47, 1951, pp. 392-396, 455-461.

9/ Clark, E. L., Hiteshue, R. W., and Kandiner, H. J., Producing Fuel Oil from Coal: Chem. Eng. Prog., vol. 48, 1952, pp. 15-20.

Generated on 2024-09-20 11:08 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Hydrogenation of Shale-Oil Coker Distillate

In a cooperative project with the Bureau's Oil-Shale Demonstration Plant near Rifle, Colo., the coal-hydrogenation pilot plant was modified to serve as a fixed-bed converter for the hydrogenation of shale-oil coker distillate.10/ This material, produced at the Demonstration Plant Shale-Oil Refinery, was hydrogenated at 1,500 p.s.i.g. pressure and 445° C. over a cobalt molybdate catalyst. About 1,500 gallons of product (97 percent recovery of liquid) was obtained; 1,300 cubic feet of hydrogen was absorbed, and 350 cubic feet of hydrocarbon gases was produced per barrel of coker distillate. The catalyst was very satisfactory for reducing the average molecular weight of the oil and for eliminating sulfur and nitrogen. The nitrogen content decreased almost directly with increasing consumption of hydrogen. A change in hourly space velocity from 1.1 to 0.9 volume of coker distillate per volume of catalyst resulted in a reduction of the nitrogen content of the product oil from 0.11 to less than 0.02 percent, a slightly higher hydrogen content of the oil, and increased production of gas. Distillation of the oil yielded 60 percent of jet fuel and 40 percent of diesel fuel meeting the requirements of military specifications MIL-F-5624 and Navy 7-0-2e, respectively. About 80 percent of the crude shale oil was converted to marketable products, hence this process appears to be economically feasible. A full-scale plant might also utilize some 5.7 pounds of ammonia and 1.9 pounds of hydrogen sulfide, which are produced per barrel of coker distillate, as well as the coke and gas obtained in the first step of the operation.

Separation, Synthesis, and Characterization of Products of Coal Hydrogenation

Phenols

The polar constituents of the oil obtained from coal hydrogenation may be divided into two broad classes, phenols and organic bases.

Twenty-two phenols, principally the simple alkyl derivatives of phenol itself, were characterized by their infrared spectra.11/ Four main divisions were made on the basis of changes in the intensity of absorption and/or the position of the band due to the hydroxyl group: (1) No ortho-substituents, (2) 1 methyl group in the ortho position; (3) a larger-than-methyl group in the ortho position; and (4) 2 methyl groups in both ortho positions. Considerable qualitative and quantitative information may thus be gained from an examination of the infrared hydroxyl spectrum of a mixture of phenols.

Phenols were separated from a mixture of isomeric, homologous, or other closely related phenols by countercurrent distribution.12/ The instrumental, operational, and mathematical aspects of this method were described in detail.13/ Under suitable conditions such work permits determination of the minimum number of components in a system, isolation of these components, determination of their purity and some of their physical characteristics, and determination of their abundance in the original mixture.

10/ Clark, E. L., Hiteshue, R. W., Kandiner, H. J., and Morris, B., Hydrogenation of Shale-Oil Coker Distillate: Ind. Eng. Chem., vol. 43, 1951, pp. 2173-2178.

11/ Friedel, R. A., Infrared Spectra of Phenols: Jour. Am. Chem. Soc., vol. 73, 1951, pp. 2881-2884.

12/ Golumbic, C., and Orchin, M., Separation of Individual Phenols from a Mixture of Isomeric Homologous or Other Closely Related Phenols: U. S. Patent 2,581,406, Jan. 8, 1952.

13/ Golumbic, C., Liquid-Liquid Extraction Analysis: Anal. Chem., vol. 23, 1951, pp. 1210-1218.

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Organic Bases

Countercurrent distribution also was applied to the characterization of organic bases.[14] The partition coefficients and approximate ionization constants of aniline and 12-methyl-substituted derivatives were determined by this procedure. The information thus obtained will be used for part of the program of analyzing and characterizing the organic base-fraction to the same extent as has been done with the phenolic fraction of the product from coal hydrogenation.

Polycyclic Compounds

The two isomers of methyl naphthalene are present in commercial quantities in coal-tar oils. In their pure states they may have important uses as organic intermediates. As no satisfactory method of separating the pure α-isomer was available, a method was developed based on the principle of azeotropic distillation at suitable reduced pressures.[15][16] An entrainer, such as commercial undecanol, is added to the mixture and forms an azeotrope with β-methyl naphthalene at about 200 mm. Hg; the azeotrope may be distilled from the mixture, leaving excess entrainer and the α-isomer in the residue. This distillation is carried out at reduced pressures, and the separated isomers as well as the entrainer are recovered in their pure form by further distillation at other pressures.

Utilization of the same principle led to a method for the purification of phenanthrene, which as isolated from coal tar, contains minor quantities of fluorene, anthracene, and carbazole.[17][18] After the removal of anthracene by reaction with maleic anhydride, fluorene in the residue is distilled as an azeotrope of diethylene glycol at 200 to 300 mm. Hg, and phenanthrene is then distilled similarly but at 20 mm. Hg, leaving carbazole in the residue. About 75 percent of the phenanthrene can be recovered in 98 percent purity.

Two types of adapters for introducing heating coils into distillation flasks were developed.[19] Such coils are helpful for maintaining smooth boiling and operating efficiency during distillation at reduced pressures.

Further confirmation was obtained for the hypothesis that the polycyclic compounds found in coal tar and coal-hydrogenation oils may be formed from simpler compounds by cyclodehydrogenation. Several polycyclic compounds were synthesized and

---

14/ Golumbic, C., and Goldbach, G., Partition Studies, VI. Partition Coefficients and Ionization Constants of Methyl-Substituted Anilines: Jour. Am. Chem. Soc., vol. 73, 1951, pp. 3966-3967.

15/ Feldman, J., and Orchin, M., Method for the Separation of α-Methyl Naphthalene from β-Methyl Naphthalene by Azeotropic Distillation: U. S. Patent 2,581,398, Jan. 8, 1952.

16/ Feldman, J., and Orchin, M., Method for the Separation of α-Methyl Naphthalene from β-Methyl Naphthalene by Azeotropic Distillation: U. S. Patent 2,583,554, Jan. 29, 1952.

17/ Feldman, J., Pantages, P., and Orchin, M., Purification and Freezing Point of Phenanthrene: Jour. Am. Chem. Soc., vol. 73, 1951, pp. 4341-4343.

18/ Feldman, J., and Orchin, M., Method for Purification of Phenanthrene: U. S. Patent 2,590,096, Mar. 25, 1952.

19/ Feldman, J., and Pantages, P., Adapters for Introducing Hot Coils into Distillation Flasks for Constancy of Ebullition: Anal. Chem., vol. 24, 1951, p. 432.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

characterized: Passage of dimesityl over a chromia-on-alumina catalyst at 500° C. resulted in the formation of 4,9-dimethylpyrene;20/ cyclodehydration of 2-(1-napthyl)-cyclohexanene followed by dehydrogenation yielded fluoranthene;21/ and vapor-phase dehydrogenation of directly joined di-aryl compounds in which one of the aryl radicals contained an ortho-substituted hydroxy group lead to the formation of di-aryl cyclic ethere.22/ A useful method for characterizing polycyclic compounds consists of forming their picrates. The fact that picrates of certain polycyclic compounds cannot be formed appears to be due to steric hindrance; nonplanarity of the hydrocarbon may prevent close approach of a picric acid molecule and weaken the stability of the complex.23/

X-ray diffraction powder patterns were obtained of 45 complexes of 2,4,7-trinitrofluorenone and aromatic hydrocarbons.24/ Such patterns are useful for purposes of identification.

SYNTHETIC LIQUID FUELS DEMONSTRATION PLANT

Coal Hydrogenation Plant

Two individual liquid-phase runs were completed at the Coal Hydrogenation Demonstration Plant in which 2,500 tons of Illinois No. 6 coal and approximately 4,000 tons of Lake DeSmet, Wyo., coal were converted to vapor-phase charging stock.25/ The middle oils produced in these runs were processed in a single vapor-phase run to yield approximately 400,000 gallons of gasoline having an octane value of 76 to 77, Motor Method.

Liquid-Phase Hydrogenation Unit

In the liquid-phase run (No. 7) on 2,500 tons of Illinois No. 6 coal, approximately 303,000 gallons of vapor-phase charge stock was produced. This coal is high-volatile bituminous obtained from the Green Diamond mine in the Marissa District, St. Clair County, Ill., and cleaned by heavy-medium separation to an ash content of 8.3 percent.

The immediate objectives were to determine process requirements and yields from this coal, using $FeSO_4$ catalyst in both light- and heavy-oil operations simulating, insofar as the plant performance permitted, throughputs and yields used in commercial-plant design and cost estimates.

The first phase of the operations was to establish conditions holding the heavy-oil yield down to 6 percent of the moisture- and ash-free coal. The second phase was

---

20/ Orchin, M., Reggel, L., and Friedel, R. A., Aromatic Cyclodehydrogenation, XI. Experiments with Dimesityl: Jour. Am. Chem. Soc., vol. 74, 1952, pp. 1094-1095.

21/ Orchin, M., and Reggel, L., A Synthesis of Fluoranthene by Cyclodehydration: Jour. Am. Chem. Soc., vol. 73, 1951, pp. 2955-2956.

22/ Orchin, M., and Woolfolk, E. O., Synthesis of Di-Aryl Cyclic Ethers: U. S. Patent 2,566,357, Sept. 4, 1951.

23/ Orchin, M., Steric Effects in Complex Compound Formation: Jour. Org. Chem., vol. 16, 1951, pp. 1165-1169.

24/ Hofer, L. J. E., and Peebles, W. C., X-Ray Diffraction Patterns of the 2,4,7-Trinitrofluorenone Derivatives of Aromatic Hydrocarbons: Anal. Chem., vol. 24, 1952, pp. 822-826.

25/ Bureau of Mines, Synthetic Liquid Fuels. Annual Report of the Secretary of the Interior for 1951. Part I. Oil from Coal: Rept. of Investigations 4865, 1952, 83 pp.

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:10 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

Digitized by Google

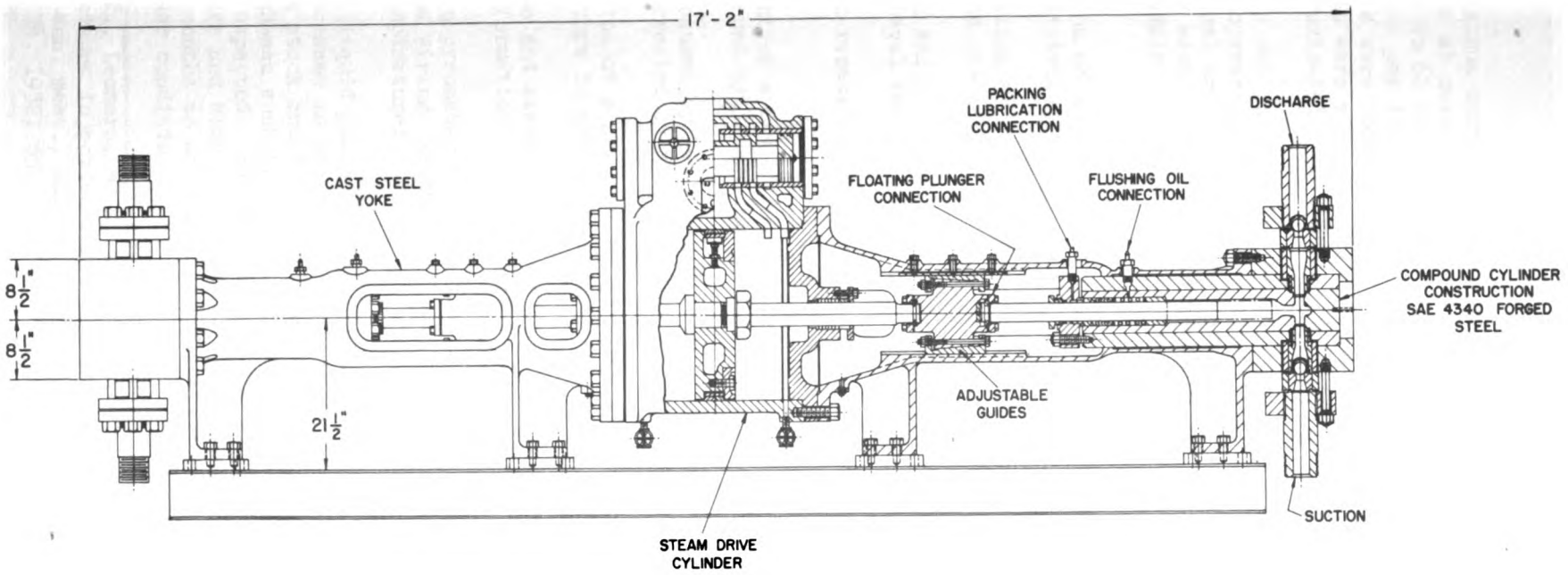

Figure 21. - High-pressure injection pump.

Original from THE OHIO STATE UNIVERSITY

to determine the maximum conversion to light oils at maximum coal throughput, and the third to operate at maximum throughput making 50-50 light and heavy oils. With coal throughputs up to 62 tons per day, the required conversion to light oils was obtained. At 70 tons per day, however, conversion to light oils dropped slightly and coal throughputs were somewhat lower than anticipated. Consequently, space-time yields of light oils were appreciably lower than design values, but hydrocarbon-gas production was approximately the same as that estimated in the design.

Although it was not possible to obtain the high throughputs and space-time yields set for the operations, the run provided additional valuable information on hydrogenating the coal and on process and equipment improvements required. An important function of each run has been development and improvement of techniques and equipment. For example, before run No. 7 was begun, the following improvements were made:

1. Installation of a catalyst hopper in the coal-preparation building to allow addition and even distribution of dry iron sulfate before the crusher.

2. Simplification of suction piping leading from the paste tank to the steam-driven reciprocating paste-circulating pumps to alleviate line plugging.

3. Relocation and lengthening of the lower hot-catchpot pneumercator tubes to improve liquid-level regulation.

4. Repair and repacking of hydrogen circulator compressors and high-pressure injection pumps.

5. Development of a new high-pressure injection pump, shown in figure 21, incorporating compound cylinder construction and other advanced features.[26]

Difficulties caused by hot spots in the second converter during the early part of the run were corrected by the following improvements:

1. Installation of a new cooling gas line with automatic controller to control the bottom temperature in this converter.

2. Insulation and steam tracing of cooling gas lines to prevent possible plugging from the formation of gas hydrates.

3. Changes in pyrometer tubes in the converters and in the hot catchpot and improvements in the wiring assembly for more effective observation and control of critical vessel temperatures.

In the second liquid-phase run (No. 8) approximately 4,000 tons of Lake DeSmet, Wyo., coal was processed in the liquid-phase plant, producing 273,000 gallons of vapor-phase charge stock and 65,000 gallons of solids-free heavy oil. This coal is high-moisture, high-ash subbituminous coal, which proved very reactive and hydrogenated well. As expected, however, throughputs and yields were adversely affected by the high moisture and high ash content. Operations on this coal were conducted during the winter months to determine the operability of the hydrogenation plant under severe weather conditions.

---

[26] Donovan, J. T., Leonard, B. H., and Markovits, J. A., Design and Development of High-Pressure Injection Pumps for Hydrogenation Service: Pres. Am. Soc. Mech. Eng. ann. meet., Atlantic City, N. J., Nov. 25-30, 1951; abs. in Mech. Eng., vol. 74, 1952, pp. 36-37.

Generated on 2024-09-20 11:06 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Insufficient coal-drying capacity limited the plant throughput to 60 tons of moisture-free coal per day. The coal had not been washed before being processed, and the high-ash content necessitated holding the light oil yield down to make enough heavy oil for solids removal. Particular emphasis was given to solving problems resulting from the high moisture and high ash content of the coal. Based on experience during the Illinois run, the following changes and improvements were made before beginning the run on Lake DeSmet coal:

1. Installation of a letdown system for desanding converters periodically to alleviate solids accumulation, particularly in the second converter.

2. Installation of new style, high-tensile pump blocks with external valves to replace the original wash-oil pump blocks.

3. Insulation and steam tracing of instrument and product lines that appeared to be in danger of freezing in cold weather.27/

4. Installation of a new bottom head on the heavy-oil let-down flash drum with immersion heaters to prevent solidification of the ash containing pitch, and subsequent coking of the equipment. (A recycle line to the feed tank, with necessary controls and a water-bed pitch conveyor, was installed to improve and simplify solids removal).

The high moisture content of the Lake DeSmet coal presented problems in drying and grinding, but experience during the run led to a number of significant changes in equipment and operations that will improve performance on similar high-moisture and high-ash coals. Changes affected between runs will result in better solids removal equipment, smoother operation of the flash-distillation unit, increased coal-drying potential, and improved Waytrol control system, more efficient control on the hydrogen flow to the outlet of the past preheater and on the hot-catchpot letdown line, and improved centrifugal pump performance.

Vapor-Phase Hydrogenation Unit

The light oils made during the Illinois No. 6 and Lake DeSmet liquid-phase runs were processed consecutively in the vapor-phase unit in one run (No. 4). Approximately 400,000 gallons of good-quality motor gasoline (76 to 77 octane, Motor Method) was produced from about 390,000 gallons of feed consumed. Before the beginning of the run, 75,000 gallons of Illinois naphtha was shipped under a cooperative agreement to the Carbide and Carbon Chemicals Co., plant at Institute, W. Va., for experimental extraction of the commercially usable tar acids and bases. In addition, sizable quantities of the liquid-phase gasolines and vapor-phase bottoms were reserved for use in liquid-phase operation, which reduced the total amount of feed stock available.

Since the extraction of tar acids and bases from the Illinois naphtha had not been completed and the resulting neutral-oil feed stock returned by Carbon & Carbide, the Lake DeSmet stock was processed first in the vapor-phase run. This run was of special interest as the feed contained an average of 17.9 percent tar acids, which is 3 times the reported permissible amount for operation without catalyst deterioration. No undue deterioration was observed, however, in this portion of the run. When this stock was consumed, the Illinois feed was introduced without interrupting operations to receive the tar-acid-free Illinois naphtha. As a result, this part of the run was unique in that the feed stock was composed mainly of gasoline and middle oil.

27/ Balcerzak, C. E., and Skillern, J. A., Performance of High-Pressure Instruments in the Bureau of Mines Synthetic Fuels Demonstration Plant: Pres. Pet. Mech. Eng. Conf., Tulsa, Okla., Sept. 24-26, 1951; abs. in Mech. Eng., vol. 73, 1951, p. 1018.

Generated on 2024-09-20 11:07 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

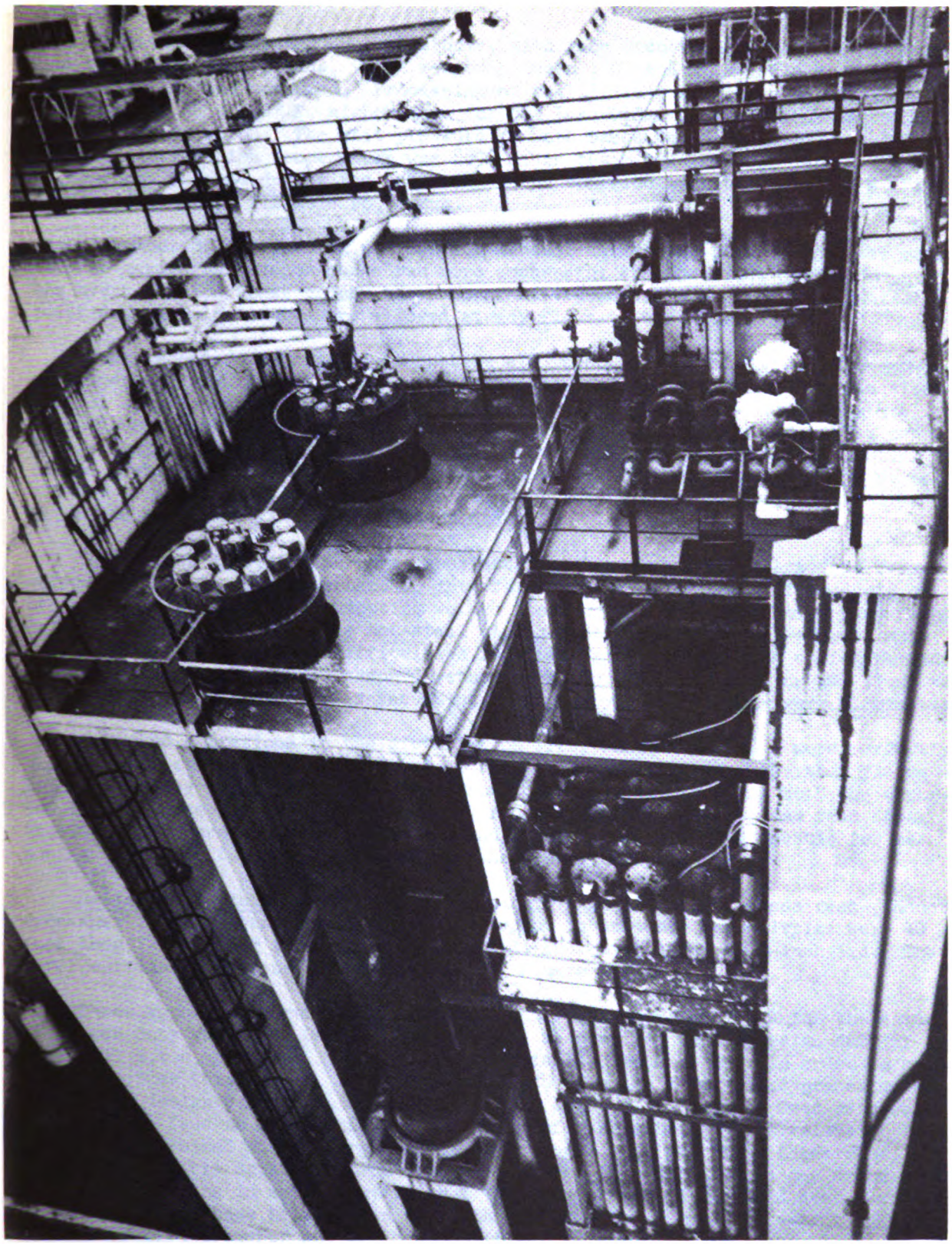

Figure 22. - Vapor-phase hot stall showing new exchanger and welded, supported piping.

Generated on 2024-09-20 11:15 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from
THE OHIO STATE UNIVERSITY

Operation was smooth on both stocks, with good reduction of the tar acids and gasoline space-time yields, which ranged between 1.00 and 1.04 gallons of gasoline per gallon of feed consumed. Processing of the Illinois stock was carried out at temperatures about 20° F. higher than for the Lake DeSmet feed, with an attendant greater gasification. The unit pressure in both cases was near 10,000 p.s.i., and the average reaction temperature was 889° F. in the middle and 898° F. in the bottom of the catalyst bed during the Lake DeSmet run compared with 910° to 920° F., respectively, during the Illinois No. 6 run.

A number of interesting process and mechanical improvements contributed materially to making this vapor-phase run more successful than previous operations. In the hydrogenation plant proper the smooth and dependable operation of injection pumps and recycle compressors allowed steady flows to units at all times.

The preheater was repiped to operate all tubes in series, and the feed-product exchanger shown in figure 22 was redesigned, arranging the flows to provide close control of gas temperatures through two sections and of the liquid temperature through the third section of the exchanger. Very successful operation of a new narrow range (800° to 900° F.), recording temperature controller in the cooling gas to the preheater outlet line allowed the converter-entrance temperature to be held closely in line, ± 2°, which is essential for close control of bed temperatures required to give best yields and product quality.

No serious difficulties were experienced with pyrometer readings, and very few valve tips became worn or broken to interfere with smooth letdown of products or other flow conditions. By adopting welded construction and eliminating many flanged joints previously used in the hot-stall piping system and by proper support and anchorage of the piping no difficulties resulted from leakage, even during periods when operating temperatures changed rather abruptly. All the cooling gas lines were steam traced, and difficulties resulting from gas-hydrate plugging were eliminated.

Improved operations in the distillation area, which supplied a more perfectly blended feed stock, also contributed to the success of this run. Further yields and product-quality improvements resulted from better fractionation in both the vapor- and liquid-phase distillation systems by redistilling the vapor-phase feed stock immediately before the vapor-phase run and through use of liquid caustic for removing traces of tar acids from the finished gasoline.

Heaters and exchangers. - The original hydrogenation vapor-phase feed-product exchanger formed 4 banks of 7 parallel hairpins in series. The hairpins were 40 feet long, with inner tubes of 1.25-inch o.d. and outer tubes 2.02-inch i.d. The total outside tube transfer surface was 733 square feet.

Three vapor-phase runs were made with this exchanger, during which the actual exchanger duty was 5,000,000 B.t.u. per hour, as compared with a design duty of 7,350,000 B.t.u. per hour. As a result of this low exchange duty in order to maintain converter temperature, it was necessary to fire the vapor-phase preheater about double its design duty of 1,500,000 B.t.u. per hour and to cut the feed rate below design. The feed to this exchanger consisted of a relatively small volume of liquid middle oil combined with a large volume of hydrogen. In the first three runs, the oil had apparently separated from the gas feed and had collected in one or more of the seven hairpins in each bank, so that the effective feed flow and heat transfer were limited to those hairpins in which the oil had not formed a stagnant "slug." To improve heat transfer and performance it was necessary to increase the feed velocity.

Generated on 2024-09-20 11:11 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

On the product side, as condensation took place, much the same situation developed, with condensate forming in one or more hairpins as a stationary plug. To reduce the effect of these liquid-filled hairpins cutting down the amount of tube heat-transfer surface the exchanger was modified to 3 parallel passes with 9 hairpins in series in each pass. At the same time, the inner tube outside diameter was increased from 1.25 inches to 1.5 inches. These changes increased the velocity so that the pressure drop was enough to prevent liquid plugging of one of the passes, and relatively equal velocities were obtained on the feed and product sides. The tube length for transfer is 34 feet 1-1/2 inches, inner tube 1.5 inches o.d. and 1.232 inches i.d., and outer tube 4.031 inches o.d. and 2.021 inches i.d. The total outer-tube transfer surface was 710 square feet.

Run 4A showed no appreciable improvement in the modified exchanger, and after this run further changes were made to achieve satisfactory operation. As the gas-product stream was distributed adequately, the product side was not modified. The inlet header on the feed side was split to send all the oil feed through 1 pass and the hydrogen feed through the other 2 passes. A small quantity of hydrogen was injected into the oil feed to prevent possible coking or polymerization of the oil, which would result in deposition of solids in the exchanger.

After the second modification run 4B proved quite satisfactory with the feed-product exchanger producing a duty of 6,900,000 B.t.u. per hour. This allowed the vapor-phase preheater duty to be reduced to 2,000,000 B.t.u. per hour, resulting in a higher feed rate than had been previously possible.

New High-Pressure Injection Pump

An entirely new pump was developed for the 10,000-p.s.i. discharge pressure required in the coal-hydrogenation process.28/ The new high-pressure injection pump to replace conventional steam-driven pumps has the following features:

1. Compound, 2-layer, fluid-end construction resulting in uniform stress distribution and smaller cylindrical walls that can be thoroughly forged and inspected before assembly.

2. Specially designed valve ports, plunger space, and stuffing box to eliminate joints and attendant bolting and sealing problems.

3. Spring-loaded, short-length, low-pressure, lubricated packing assembly.

4. Fine machine finish on all internal surfaces to eliminate stress raisers.

5. In-line construction, with positive plunger guiding through entire stroke.

Three duplex pumps and one simplex pump of this design have been placed in service; to date, their performance has been most encouraging.

A new packing assembly was developed for the recycle hydrogen compressors, again utilizing the principle of low-pressure lubricant injection at the low-pressure end of the packing. This design, if satisfactory, will simplify packing design for compressors and consequently reduce both original costs and maintenance.

28/ See footnote 26.

Generated on 2024-09-20 11:14 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

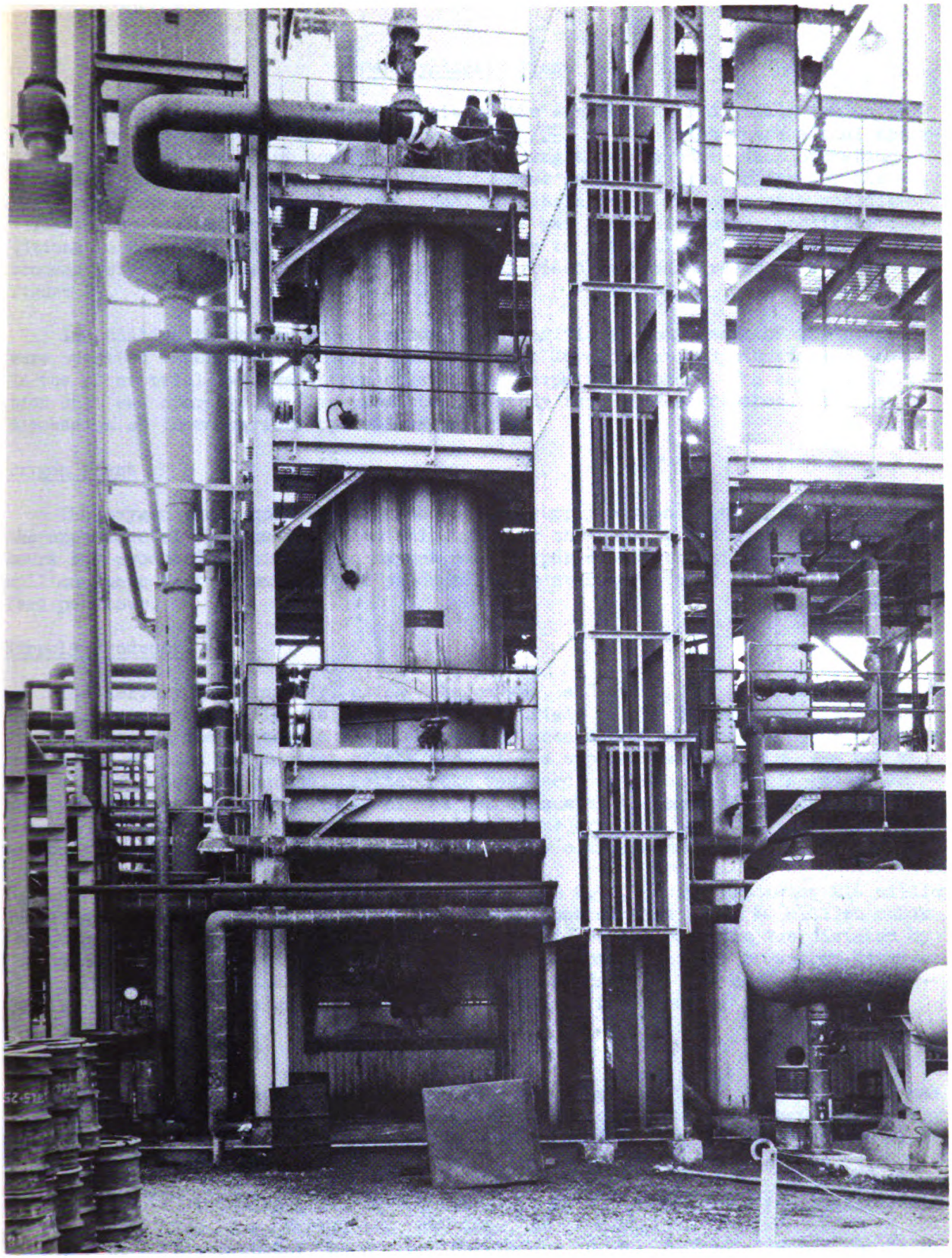

Figure 23. - Fischer-Tropsch synthesis reactor (center), looking south.

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Gas-Synthesis Plant

Completion of the preliminary trials of the synthesis and distillation units brought the Gas Synthesis Demonstration Plant[29/30] to the point where actual operation of the complete plant could be begun. During the year three such operating periods of the entire plant were achieved. These served to develop further the gas production and purification processes, to "shake down" the synthesis and distillation units, and to determine the levels of gas conversion under specified conditions in the synthesis unit. Some alterations to the equipment and changes in the process were made between runs. The Fischer-Tropsch synthesis reactor is shown in figure 23.

In addition to these three periods, some individual components of the plant were operated experimentally for further process development. Synthesis gas used in the plant trials was made from coke in the Kerpely producer. The coal-gasification unit was operated as time permitted to study this process further. A brief discussion of these various operations follows:

Oxygen Plant

The oxygen plant operated as necessary to supply oxygen to the producer or to the experimental coal-gasification unit. During the year it was operated over 4,000 hours and produced specification oxygen over 90 percent of the time. More than 85 million cubic feet of oxygen were produced at an average rate of about 21,000 cubic feet per hour.

Kerpely Producer

The Kerpely gas producer, using coke, oxygen, and steam, was operated on a routine basis to supply synthesis gas as required for trials of the purification section or for feed gas to the synthesis plant. Troubles encountered were minor, except for one period of high tar content of the product gas apparently caused by coke of too high volatile-matter content. Better coke was used, and one of the electrostatic precipitators was relocated ahead of the gas exhauster to correct this condition. The second precipitator was kept in service in its original position after the exhauster to make a final cleanup of the gas to the compressors.

During the year the producer was in operation 2,500 hours, producing 214 million cubic feet of gas. To generate this gas, 2,800 tons of coke, over 40 million cubic feet of oxygen, and 3,400 tons of steam were used. Gas composition was dictated by the needs of the synthesis plant but usually was about 18 percent of carbon dioxide, 38 percent of hydrogen, and 42 percent of carbon monoxide. In every case, the productive capacity of the unit was above that required for feed.

Purification Plant

The gas-purification section was operated on a routine basis to purify feed gas for the three synthesis runs and experimentally for several shorter periods. During these latter times tests were conducted that were designed to lead to more efficient or more reliable operation.

29/ Kastens, M. L., Hirst, L. L., and Dressler, R. G., An American Fischer-Tropsch Plant: Ind. Eng. Chem., vol. 44, 1952, pp. 450-466.

30/ Hirst, L. L., Dressler, R. G., and Batchelder, H. R., Bureau of Mines Completes Gas-Synthesis Plant: Crane Valve World, vol. 48, No. 1, 1951, pp. 98-103.

Generated on 2024-09-20 11:10 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The original design called for treating compressed gas to remove most of the carbon dioxide and hydrogen sulfide by scrubbing with diethanolamine, after which the gas was passed through beds of iron oxide to remove residual hydrogen sulfide. Organic sulfur was to be removed by adsorption on active carbon. This was to be followed by a hot treatment in beds of iron oxide-sodium carbonate mixtures to remove any residual traces of organic sulfur. This treatment had been used in Germany at atmospheric pressure with some success. However, it was found in the early trials that under pressure some side reactions occurred that led to evolution of heat and very difficult temperature control. This led in one case to overheating and failure of a vessel wall. As the active carbon adsorption had proved very successful and as the soda-iron treatment was expensive as well as troublesome, it was decided to eliminate it from the purification scheme. In all operations since, the active carbon has been the final purification step.

During the two longest periods of supplying gas to the synthesis, the purification unit was in operation 1,300 hours. The feed gas totaled almost 100 million cubic feet, and over 80 million cubic feet of purified gas was produced. This purified gas averaged 2.3 percent CO_2 and 0.01 grain of total sulfur per 100 cubic feet (0.2 part per million). The original requirement was that this final total sulfur content be less than 0.1 grain per 100 cubic feet. During these periods of operation approximately 15 million cubic feet of carbon dioxide was removed.

Studies during the experimental and routine operation of the purification plant led to modifications which reduced the losses of diethanolamine from the system, permitted continuous purification of the amine, increased the time between regenerations of the active carbon, and simplified the carbon regeneration procedure. The diethanolamine operation differs from the conventional in that amine concentrations up to 50 percent were used and found to be feasible where circumstances make a strong solution desirable.

It is believed that the performance of the purification section during the last two synthesis runs demonstrated adequately that the routine purification of synthesis gas to a purity well beyond the present requirements of the synthesis can be achieved reliably and economically.

Synthesis and Distillation Units

Synthesis run 1. - The first run was essentially exploratory. The oil used to cover the reduced catalyst during storage and that used for coolant were known to contain some sulfur compounds, which would cause a low catalyst activity but would be decontaminated by the operations and then be suitable for use in subsequent operations. Following a stepwise induction period of 4 days, conversions averaging 31 percent were obtained at 550° F., 330 p.s.i.g. operating pressure, and a space velocity of 531 volumes per volume per hour over the remaining 4 days of the operating period.

Although the run was short, the desired purification of the coolant oil was achieved, the operators gained valuable experience in the actual operation of the equipment and process, and the need for changes in equipment, piping, and instrumentation was clearly demonstrated.

Many changes were made between runs, such as alterations in the circulating-oil piping to permit measurement of coolant oil flow during startup operations, installation of bypass connections around the check valves in the discharge lines of the coolant-oil circulating pumps (fig. 24) to permit warming up pumps before operation, modification of entrainment separators, and installation of surge chambers in the

Generated on 2024-09-20 11:16 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-20 11:05 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

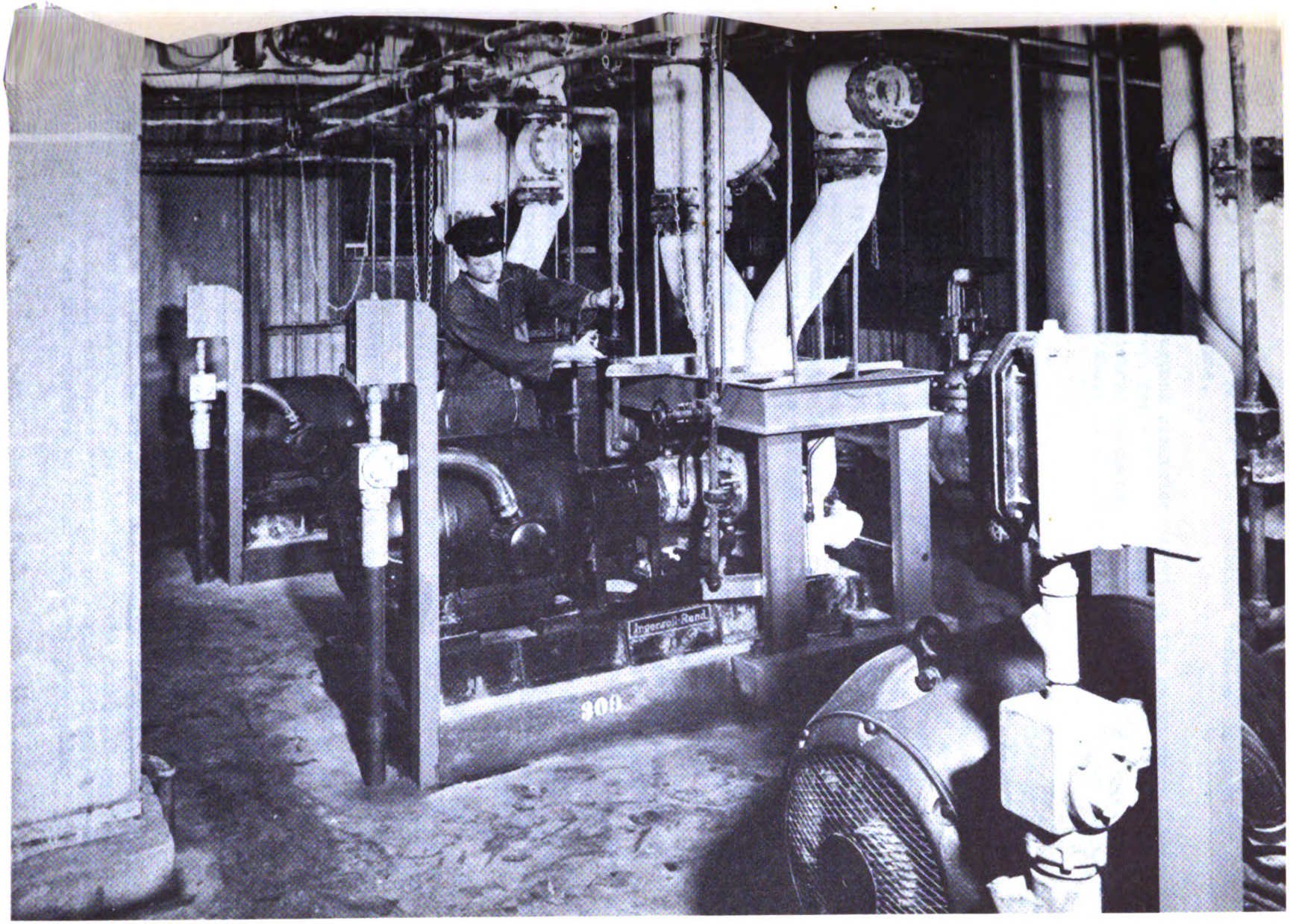

Figure 24. - Coolant oil-circulating pumps in synthesis unit of gas-synthesis plant.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

discharge lines of some pumps. Most of these changes resulted in improved and smoother operation in later runs.

Synthesis run 2. - The second plantwide operation was begun about 6 weeks after the first and continued 26 days for a total on-stream time of 591 hours. Although some difficulties were experienced in operating the synthesis and distillation units during the cold weather, satisfactory results were obtained, and much information was gained.

In this case the reduced catalyst was stored under Harnes diesel oil, a product of the Fischer-Tropsch synthesis from Harnes, France, and under "Primol D," a refined white hydrocarbon oil - both known to be sulfur-free. The coolant oil used was a mixture of "conditioned" coolant oil from the first synthesis run and Primol D. As in the first synthesis run, a stepwise induction procedure of 4 days was employed. Following induction 2 weeks of operation under fairly uniform conditions was terminated by an interruption to the high-pressure steam supply to the Gas-Synthesis Demonstration Plant. In these 2 weeks at 525° F. and 330 p.s.i.g., the fresh synthesis gas feed rate was 63,400 std. c.f.h. to give a space velocity of 555 volumes per volume per hour. A recycle ratio of 1.58:1 was employed during this period. The hydrogen-carbon monoxide ratio in the fresh synthesis-gas feed was 0.80. Average conversion was 79.5 percent, with a maximum conversion of 87.4 percent.

Operations were resumed about 24 hours after the interruption and continued an additional 7 days. During this period at 525° F. and 330 p.s.i.g. the fresh synthegas feed rate was 64,000 std. c.f.h. to give a space velocity of 560 volumes per volume per hour. The recycle ratio was 1.59:1, and the hydrogen-carbon monoxide ratio in the fresh synthesis gas feed was 0.89. The gas conversions were appreciably lower during this latter period, averaging only 73.2 percent. Pilot-plant data had indicated that a marked loss in catalyst activity might result from such interruptions

During the entire synthesis run 2, approximately 14,300 gallons of synthetic oil was recovered. This was only a partial recovery of products, as little or none of the C_3 and C_4 hydrocarbons were recovered and converted to polymer gasoline, which normally should constitute one-fourth to one-third of the gasoline product.

Trial runs of the "Perco" catalytic reforming unit were conducted after conclusion of the other plant operations. In these operations approximately 9,000 gallons of debutanized gasoline was treated. Some improvement in octane number and other characteristics was noted, but it is believed that with higher temperatures and space velocities, still further improvement can be achieved. About 800 gallons of diesel oil recovered was rerun to remove low-boiling material and the entire fraction was caustic washed. The treated diesel oil met all requirements of Military Specification MIL-D-896, class 1, and had a cetane rating of 60 (minimum for specification is 50).

The abnormally cold weather increased the difficulty of operation of coolant-oil-circulating pumps, entrainment separators, and control instruments, and indicated the need for better insulation and provisions for cold-weather operation. Most of the necessary connections were made during the period following this run.

Synthesis Run 3. - In this operation it was proposed to explore the feasibility of obtaining conversion approaching 90 percent at a fresh synthesis-gas feed rate of 65,000 to 67,500 std. c.f.h. and space velocities of around 600 volumes per volume per hour. The data from this run have not been completely evaluated.

524-71

Generated on 2024-09-20 11:04 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The catalyst employed in this run was made and reduced in the catalyst fusion and reduction units during the winter and early spring of 1952. The product catalyst averaged 87 percent reduced and was stored under Primol D oil. The coolant oil employed was a mixture of Primol D oil and recovered coolant oil from previous operations.

The induction procedure was the stepwise method employed in the first two synthesis runs. In this run the heating during induction was interrupted for several hours to replace seals on the coolant-oil circulating oil pumps after which the run continued through 14 days when the seals again needed replacing. During those 2 weeks a fresh synthesis-gas feed rate of 63,800 to 66,300 std. c.f.h., a recycle ratio of 0.955 to 1.45, and a temperature of 535° F. were maintained. Conversions were less than expected, being about 65 percent. On restarting, the fresh synthesis gas feed rate was cut to approximately 40,000 std. c.f.h., the recycle ratio held in the range of 1.80 to 2.11, and the temperature held at 535° F., to give conversions of 80 to 83 percent.

Catalyst Fusion and Reduction Units

During the year about 42,000 pounds of synthesis catalyst were made from mill scale and added promoters by the electrical fusion process. This catalyst was sized 8- to 18-mesh, as required for the synthesis.

About 18,000 pounds of this catalyst were reduced by hydrogen in the catalyst reduction unit to yield 13,000 pounds of reduced catalyst. The reduced catalyst was stored under Primol D oil, and was used in synthesis run 3.

Coal Gasification

Twelve experimental trials were made of a new coal-gasification unit to which powdered coal is fed, suspended in oxygen, and steam superheated to 1,000° F. is added through a second nozzle. A Wyoming coal was used in all but the last run, in which an Illinois No. 6 coal of low-fusion ash was used to facilitate slag-tapping. Some very promising results were achieved, but periods were encountered in which the results corresponded substantially with those of the previous unit. The original feed system to the new unit was revised during the experimental trials and improvements were made to facilitate removal of molten slag.

In view of the considerable interest in the possibility of producing ammonia synthesis gas from coal some investigations were conducted on various processes. One method of producing the required gas composition is to feed to the gasification unit an air-oxygen mixture of approximately 55 percent oxygen, and one trial was made on the coal-gasification unit to determine roughly if such an operation was practical. The results were substantially as anticipated and indicate the feasibility of this method of operation.

When the coal-gasification work was undertaken at Louisiana, Mo., a study was made of the thermodynamic relationships of this process. This earlier study was useful in predicting the maximum theoretical yields and compositions but furnished little information as to the rate at which the various changes occurred or the extent to which the reactions would be completed in a given time. After a survey of literature on the effect of time and temperature on the yields and compositions, equations were set up for the various reactions involved in the gasification of coal with oxygen. Ordinary methods would be impractical for solving many of the simultaneous equations involved; but, fortunately, they could be set up in a form suitable for calculation on the ENIAC computer at the Explosives and Physical Sciences Division at Pittsburgh. The completed calculations would make it possible to compare

Generated on 2024-09-20 11:06 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

calculated with actual experimental results, and it is hoped that the comparison will lead to a clearer understanding of the process and provide a means for controlling or predicting the operation of a coal gasifier.

Engineering Studies and Cost Estimates

Rising equipment and labor costs, higher product values, demonstration-plant operations, and the increasing demand for chemicals that could be readily produced or recovered in a coal-hydrogenation plant were factors leading to the decision to revise the findings of the 30,000-barrel-per-day coal hydrogenation-plant cost estimate. The revision was submitted to the National Petroleum Council and received considerable treatment in technical literature.31/

The revised report contained the following conclusions:

The overall capital investment for a 30,000-barrel-per-calendar-day coal-hydrogenation plant, processing Wyoming bituminous coal, is $414,440,000, including the coal mine, the power plant, working capital, and employee-housing assistance. The total value of products, which includes benzene, toluene, xylene, tar acids, gasoline, LP-gas, sulfur, and ammonia at current market prices, is $73,605,000 per annum. Using a 60- to 40-percent ratio for funded and equity capital indicates that the average return for that type of plant would be 6.98 percent. On the same basis, except that no housing assistance is charged to the plant, the capital investment for a plant processing Western Kentucky coal is $404,120,000, and the average return is shown to be 10.84 percent. In preparing the list of products and their values, only those chemicals that could be readily produced or recovered were included. Where a market survey indicated the total quantities that could be produced could not be assimilated in the market, the quantities produced were limited to the potential market.

SYNTHETIC LIQUID FUELS PUBLICATIONS

Several reviews and summaries were published during the year. They included a book review32/ and reviews of the development of the science of synthetic liquid fuels,33/ mass spectrometry in synthetic liquid fuels research,34/ and progress in fluid dynamics during 1951.35/ All of the results of work on fluid flow through packed and fluidized systems performed at the Bruceton laboratories of the Bureau since 1946 were assembled.36/ The patent section of the bibliography on pressure hydrogenation appeared37/ and the index is in preparation. A similar survey of the Fischer-Tropsch literature is being completed. The bimonthly bulletin Synthetic Liquid Fuels Abstracts was discontinued at the end of 1951 because of lack of funds.

31/ Coal Hydrogenation - More Cost Data: Chem. Eng., vol. 59, No. 6, June 1952, pp. 159-161.

32/ Storch, H. H., review of Progress in Coal Science edited by D. H. Bangham: Jour. Phys. Colloidal Chem., vol. 55, 1951, pp. 1109-1110.

33/ Fieldner, A. C., Gauger, A. W., and Yohe, G. R., Gas and Fuel Chemistry: Ind. Eng. Chem., vol. 43, 1951, pp. 1047-1048.

34/ Friedel, R. A., and Sharkey, A. G., Mass Spectrometry in Synthetic Fuels Research: Consolidated Eng. Corp. Recordings, vol. 5, No. 3, September, 1951, pp. 1, 5, and 10.

35/ Leva, M., and Weintraub, M., Fluid Dynamics: Ind. Eng. Chem., vol. 44, 1952, pp. 68-75.

36/ Leva, M., Weintraub, M., Grummer, M., Pollchik, M., and Storch, H. H., Fluid Flow Through Packed and Fluidized Systems: Bureau of Mines Bull. 504, 1951, 149 pp.

37/ Wiley, J. L., and Anderson, H. C., Bibliography of Pressure Hydrogenation. II. Patents: Bureau of Mines Bull. 485, 1951, 286 pp.

Int. - Bu. of Mines, Pgh., Pa.

Generated on 2024-09-20 11:11 GMT / https://hdl.handle.net/2027/osu.32435030643647
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY